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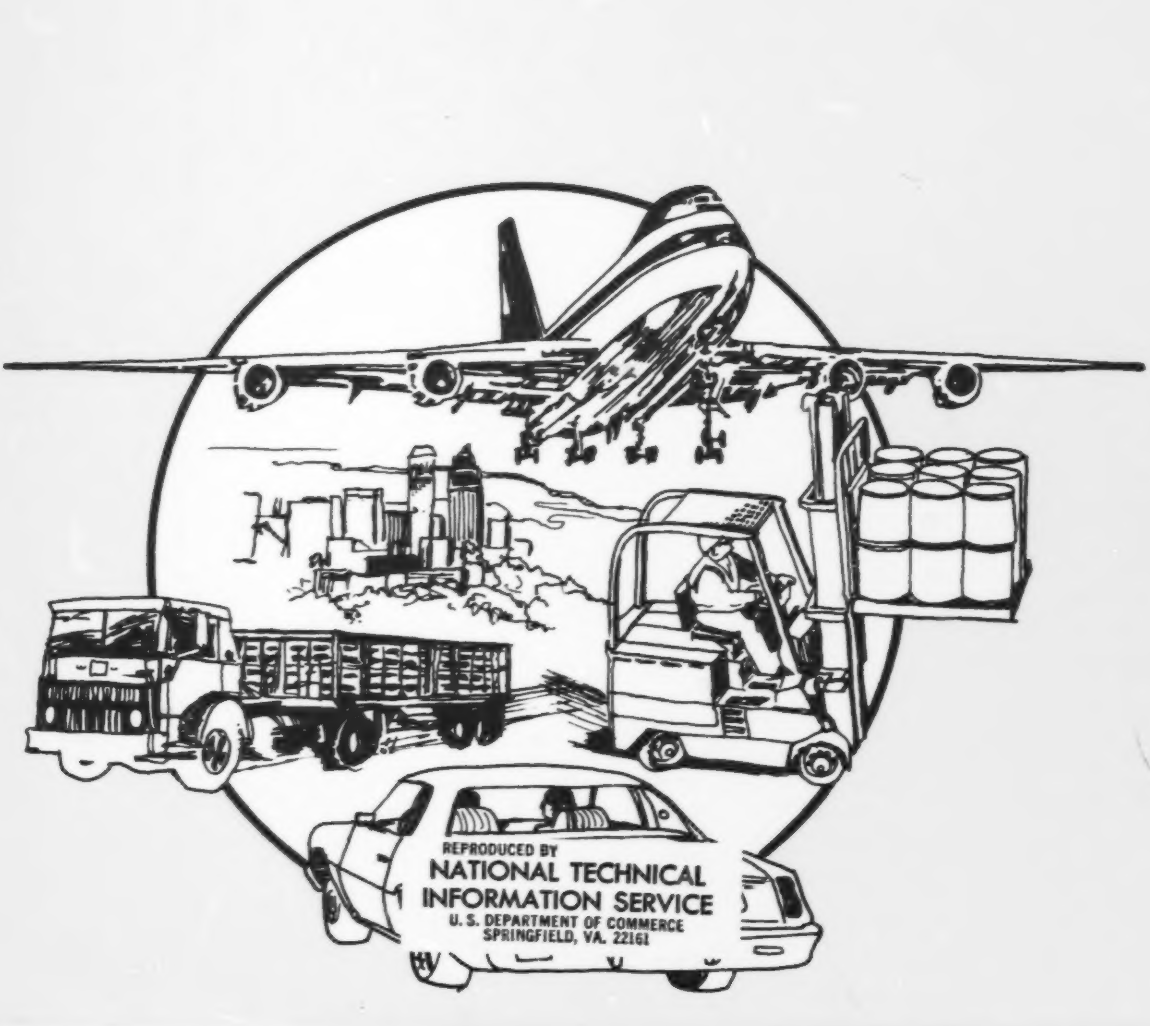
NOISE TECHNOLOGY RESEARCH NEEDS

AND

THE RELATIVE ROLES OF THE FEDERAL GOVERNMENT AND THE PRIVATE SECTOR



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This Symposium was a direct response to the provisions of the Quiet Communities Act as well as the latest step in EPA's program of coordinating noise-technology research. The Symposium was carefully focused on identifying future research needs and not on the suitability or practicality of on-going efforts of the Federal and State governments to regulate noise emission levels of products, based on current or available technology. The findings resulting from the Symposium apply directly to technology areas. Matters such as operating procedures of aircraft, administrative controls in the workplace, and health effects were not included.

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Proceedings
of the
EPA Noise Technology Research Symposium
January 29-31, 1979
Dallas, Texas

Office of Noise Abatement & Control
U.S. Enviromental Protection Agency
Washington, D.C. 20460

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The views, conclusions, and recommendations contained in this report are those of the Symposium participants and do not necessarily reflect the official policy or position of the U.S. Environmental Protection Agency.

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PREFACE

A special motivation for the Noise Technology Research Symposium was the Congressional mandate expressed in the Quiet Communities Act of 1978. The Act emphasized and expanded beyond the authorization of the Noise Control Act of 1972, EPA's charter to conduct and finance noise-control research.

The Quiet Communities Act directs EPA to: ". . .in cooperation with other Federal Agencies and through the use of grants, contracts, and direct Federal actions. . .(b) conduct or finance research directly or with any public or private organization or any person on the effects, measurement, and control of noise, including but not limited to . . . (2) investigation, development, and demonstration of noise control technology for products subject to possible regulation under sections . . . of this Act. . . ."

In addition to conducting or financing research, the Noise Control Act of 1972 gave to EPA the responsibility for coordinating the programs of all Federal Agencies and Departments relating to noise research. The Act also required EPA to publish a report of the on-going Federal research programs that identified their status and progress and contained an assessment of their contributions to the national noise effort.

Reports were published in 1977 by three Federal Interagency Panels that addressed the technology areas of machinery and construction equipment,[1] surface transportation,[2] and aviation.[3] These reports reviewed and assessed from the perspectives of the representatives of the various Federal Agencies and Departments, the noise technology research programs sponsored by the Federal Government between fiscal years (FY) 1975 and 1978.

This Symposium was a direct response to the provisions of the Quiet Communities Act as well as the latest step in EPA's program of coordinating noise-technology research. The Symposium brought together a far larger group with greater diversity of interests and perspectives than just those Federal Agencies involved in writing the Interagency Panel Reports. Where previously only Federal Agencies were involved, now emphasis was placed on participation by non-government private sector entities as well as representatives of other countries.

This Symposium was carefully focused on identifying future research needs and not on the suitability or practicality of on-going efforts of the Federal and State governments to regulate noise emission levels of products, based on current or available technology. By definition no research or demonstration is necessary to prove the feasibility of technology which is available--i.e., in limited use within the industry or in use in similar products--although demonstrations of the applicability of the technology may be deemed helpful. This Symposium focused on the need for developments above and beyond those presently being used or available and consequently, the Symposium results should not be read as criticism or comments on any present rulemaking activity.

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[1] Federal Research, Development and Demonstration Programs in Machinery and Construction Noise, prepared by the Federal Interagency Machinery and Construction Noise Research Panel, EPA 550/9-78-306, Washington, D.C., February 1978.

[2] Federal Research, Development, and Demonstration Programs in Surface Transportation Noise, prepared by the Federal Interagency Surface Transportation Noise Research Panel, EPA 550/9-78-305, Washington, D.C., February 1978.

[3] Federal Research, Technology, and Demonstration Programs in Aviation Noise, prepared by the Federal Interagency Aviation Noise Research Panel, EPA 550/9-78-307, Washington, D.C., March 1978.

The findings resulting from the Symposium apply directly to technology areas. Matters such as operating procedures of aircraft, administrative controls in the workplace, and health effects were not included. More especially in the case of aviation, the findings relate to the aircraft itself rather than the total operation; the total systems concept was not addressed.

The results of the Symposium, as they appear in these proceedings, will by means of this report be made available to the Federal Agencies and Departments, to the industries represented at the Symposium, and to the general public. It is hoped that the recommendations of this report will be considered by these entities, and that the report results will influence the rate of progress in solving technological problems in noise control through their effects on budgets, through the establishment of cooperative efforts, and through the establishment of a basis for the continuing exchange of ideas and results between the public and private sectors.

ACKNOWLEDGMENTS

The success achieved at this Symposium, judged in terms of the cooperation and communication that occurred between the Federal Government and the private sector, and the wealth of information obtained with respect to the objectives is attributable to the enthusiastic support provided by the advisors and contractors that helped plan this Symposium, as well as all of the participants.

Particular thanks are extended to the members of the Project Advisory Committee (PAC), who served as chairmen and co-chairmen of each of the workshops and the members of their supporting advisory panel. The PAC gave very generously of their time during the six months involved in planning and conducting the symposium. The PAC served as the principal advisory and supporting group to EPA assisting in all aspects. In particular, they helped to identify all of the objectives that needed to be met, the participants to be invited, and all of the issues that needed to be addressed, to specify the mechanics of operating, and to manage the conduct of the symposium. The advisory panel members provided additional specialized depth and perspective to the above in each of their respective areas of interest:

Machinery and Construction Equipment
Surface Transportation
Aviation

In addition to their participation in group activities, individual panel members gave their time freely and enthusiastically when special assistance was needed.

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The Project Advisory Committee members were:

- Dr. Franklin D. Hart, Director, Center for Acoustical Studies, North Carolina State University (Chairman of the Machinery and Construction Equipment Workshop)
- Mr. J. Alton Burks, Supervisory Acoustical Engineer, Bureau of Mines, Department of Interior (Co-Chairman of the Machinery and Construction Equipment Workshop)
- Mr. Terrence A. Dear, Senior Consultant, Engineering Service Division, E.I. Du Pont de Nemours & Company (Co-Chairman of the Machinery and Construction Equipment Workshop)
- Mr. Edwin G. Ratering, Director, Vehicular Noise Control, General Motors Corporation (Chairman of the Surface Transportation Workshop)
- Mr. Bernard J. Vierling, Director, Office of Bus and Paratransit Technology, Urban Mass Transit Administration, U.S. Department of Transportation (Co-Chairman of the Surface Transportation Workshop)
- Dr. Jack L. Kerrebrock, Head, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology (Chairman of the Aviation Workshop)
- Mr. Harvey H. Hubbard, Assistant Division Chief, Acoustics and Noise Reduction Division, NASA Langley Research Center (Co-Chairman of the Aviation Workshop)

The Advisory panel members were:

Machinery and Construction Workshop Panel

- Mr. Stephen M. Blazek, Assistant Director, Ship Silencing Division, Research and

Technology Directorate, Naval Sea Systems Command (SEA 037B), Department of the Navy

- Mr. Robert Bruce, Deputy Division Director, Physical and Environmental Control, Technologies Division, Bolt Beranek and Newman, Incorporated

- Mr. George M. Diehl, Consultant, Ingersoll-Rand Company

- Dr. Uno K. Ingard, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology

- Mr. John J. McNally, Manager, Product Safety and Environmental Control, Caterpillar Tractor Company (Representing Construction Industry Manufacturers Association (CIMA))

- Mr. Allan Teplitzky, Manager, Acoustics, Consolidated Edison Company of New York

Surface Transportation Workshop Panel

- Dr. Erich K. Bender, Manager, Applied Technology, Bolt Beranek and Newman, Incorporated

- Dr. Tony F. W. Embleton, National Research Council, Canada

- Dr. Robert Hickling, Departmental Research Engineer, Engineering Mechanics Department, General Motors Research Laboratories

- Mr. Eugene Lehr, Chief, Environmental Coordination Division, U.S. Department of Transportation

- Mr. Robert L. Mason, Office of Energy and Environment, Transportation Systems Center, U.S. Department of Transportation

- Mr. Rodger F. Ringham, Vice President, Engineering, International Harvester

- Mr. Ronald J. Wasko, Manager, Acoustics and Electromagnetic Department, Motor Vehicle Manufacturers Association

Aviation Workshop Panel

- Dr. Gordon Banerian, Program Manager, Head of Acoustics, Research and Technology Division, NASA Headquarters
- Mr. Walter Collins, Noise Abatement Officer, Los Angeles Department of Airports
- Mr. Charles Cox, Group Engineer, Acoustics, Bell Helicopter
- Mr. Harry W. Johnson, Program Manager for General Aviation, NASA Headquarters
- Mr. Robert Lee, Manager, Acoustics Design Technology, Aircraft Engine Group, General Electric Company
- Mr. Aubert L. McPike, Director, Industry Association Activities, McDonnell-Douglas Aircraft Corporation
- Mr. John Tyler, Consultant, National Organization to Insure a Sound-Controlled Environment (NOISE)

The support provided at the Symposium by the subgroup leaders is very much appreciated (refer to Appendix B). They effectively guided and persuasively stimulated the necessary dialogue.

Thanks is extended to the participants for their time expended, openness in discussion, and support provided. Without their support this Symposium would not have been a success. The support of each of the organizations (e.g., industrial, Federal, etc.) that enabled their employees or representatives to contribute their time and efforts in what we believe was a very important endeavor is also appreciated.

The cooperation and assistance of the various Federal Agencies and Departments involved in noise technology research that provided advice, information on their programs, and representatives to present these programs, as well as participate on the discussions is very much appreciated:

DOD (Army, Navy, Air Force), NASA, DOT and its operating modes (FHWA, UMTA, FRA), DOI (BOM), NSF, HEW (NIOSH). We would in particular like to extend special thanks to NASA for their extensive support.

Appreciation is expressed to the contractors that supported this effort. Verve Research Corporation (Ms. JoAnn Hairston, Program Manager), for assistance in planning and the administrative support provided at the Symposium. Dr. William Benson and Mr. Reynold Greenstone of ORI, Inc. for support in reviewing the information obtained at the Symposium and support in preparing the final report.

This entire project was carried out under auspices of the Technology and Federal Programs Division of the Office of Noise Abatement and Control at EPA. Mr. John C. Schettino, Director of the Technology and Federal Programs Division and Mr. Harvey J. Nozick, Chief of the Technology Branch, conceived the need for a symposium and provided guidance and direction in its conduct. Program management was provided by Mr. Roger W. Heymann, Program Manager, and Mr. Thomas L. Quindry, Project Officer.

EXECUTIVE SUMMARY

Hazardous as well as intrusive environmental noises that degrade the quality of life are continuing and ubiquitous problems of contemporary society. Recognizing the magnitude of noise problems and seeking to alleviate them, Congress, through the Quiet Communities Act of 1978, gave new directives to the U.S. Environmental Protection Agency (EPA) to support research in noise abatement technology. This Symposium on Noise Technology Research was the first response of the EPA to the new Congressional directives.

The Symposium was held on January 29-31, 1979, in Dallas, Texas. Over 200 invited participants, representing a broad spectrum of noise-related interests and expertise, provided a comprehensive assessment of current needs in noise-abatement technology, a comprehensive review of current research to determine which needs may not be met by current research, and a set of recommendations for research that should take precedence in fulfilling unmet needs. The Symposium participants also gave their recommendations as to the roles of Government, universities, and industry in performing the necessary research.

OVERVIEW

While in general a fundamental understanding of machinery and construction equipment noise, surface transportation noise, and aviation noise exists, the need for further research was identified if significant noise reductions are to be achieved in the future. Despite the fact that the noise abatement technology of each of the three problem areas is

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at a different level of development, each area is at a level where more experiments, analyses and demonstration of technology must be done if further improvements are to be achieved.

The Federal Government has a function to perform noise technology research. To complement industry's research efforts to develop and market quieter products, the Government should support basic research and conduct cooperative demonstration projects to encourage and promote the acceptance of available technology. Research that has a high risk or that will involve a long delay until applicable results are achieved is a necessary Government function. The private sector, on the other hand, while expected to conduct basic research must have the responsibility for product development ("low-risk" research). The Government must act as a coordinator between Federal and private research programs, and the private sector has a responsibility to participate in the coordination activities. Further, the Government should furnish a single office for exchange and dissemination of information on noise technology research. The private sector should participate in activities (e.g., symposia, workshops, and technical information service) devised to facilitate exchange of information.

With respect to industrial machinery, the ability to design and develop or even to redesign existing equipment and processes to meet significantly reduced noise levels is lacking. This lack has prevented development and integration of technology that would reduce noise and yet meet the requirements of high productivity necessary if industry is to compete in domestic and foreign markets. In many situations it has been impossible for industry to introduce acceptable, quiet equipment because such equipment does not exist.

Present noise control technology is limited with respect to surface transportation vehicles. Many principal sources of noise associated with surface transportation vehicles (e.g., diesel engines, tire-roadway interaction, and wheel-rail interaction) are common to many classes of vehicles or large segments of the industry. The ability to significantly reduce the noise from these few principal sources would result in reductions for a great many particular noise sources.

Past technology has enabled the aircraft industry to make large gains in reducing aircraft noise. Additional gains can be expected from applying present technology, however a greater fundamental understanding will be needed if greater progress is to be achieved.

FINDINGS OF THE MACHINERY AND CONSTRUCTION WORKSHOP

Very little research is currently being done to develop new equipment and processes to meet required lower noise levels. Rather, almost all research is directed to finding retrofit technology to shield equipment now in use. A relatively large number of machines and processes in each of the primary industries (metal fabrication; wood, paper; chemical, petroleum, electric utility; food, tobacco, glass; textile, printing; underground and surface mining, and related processing plants; construction) was identified as needing research.

All of the industrial subgroups concluded that some products and processes in their industries required some Federal support of research. Each of the subgroups indicated that an essential function of the Federal Government is to support research that would advance basic knowledge and lead to the development of noise control technology and expertise where demonstrated needs exist. There are five specific roles for the Federal Government in developing noise control technology.

First, the need for limited Federal Government involvement in machinery and construction equipment noise control RD&D was recognized. The activities of the Federal Government must be directed at meeting well-documented needs. The Federal effort must be coordinated with and complement efforts of the private sector. More specifically, the Federal effort can complement the private effort by doing high-risk research that needs to be done where the private sector is unwilling or unable to do it. Small manufacturers, for example, will be particularly in need of assistance because they do not have the capital to invest in research nor the expertise necessary to take an initiative in noise control.

Second, the Federal Government has a role to participate in, support, and provide technical coordination for demonstration projects. There were some differences in the need felt for Government participation among different industry groups, and the differences may, to some degree, result from differences in available noise control technology; the more primitive the technology, the more need there is for technology development and the less need for demonstration. As a consequence, it was observed that there will be less need for research and more need for demonstration as research, in due course, produces solutions to noise control problems.

Third, the Federal Government has a role to play in coordinating research activities within the Government and between the Government and the private sector. The need for a focal point within the Federal Government to facilitate communications and coordination with the private sector was defined. The focal point would also serve as a means for allowing the private sector to influence the conduct and planning of Federal research programs by means of a joint committee with representatives from Federal Departments and Agencies, universities, and industries. A joint committee would serve to ensure that national noise goals and priorities, training needs to provide future expertise in noise control technology, and the constraints imposed by practical working conditions are all being met.

Fourth, it was recognized that some Federal Agencies have unique needs unrelated to those of the private sector. For example, the DOD's activities with respect to artillery is unique as far as the private sector is concerned. Those Agencies with a mandate to do so will have to conduct appropriate research to meet particular mission needs.

Fifth, the Government also has a role in collecting and disseminating information. This role can be performed as part of the coordination role; that is, the center for coordination could include a technical information center. The need for a centralized source of information was most strongly felt by the machinery workshop, probably because the other workshops represent much more centralized industries. Further, both aviation and surface transportation have had a heavy involvement in Government and privately funded noise control research for quite a long period of time, whereas noise control research in machinery and construction equipment is in its infancy. Thus the machinery industries have not had sufficient time or experience in ways of communicating with each other and with the Government. Further, since most machinery noise control efforts to date have used enclosures for retrofit, there would be little benefit in communicating because each particular workplace is unique.

The private sector has an important role in developing noise control technology, for industry possesses the detailed knowledge of the problems that must be solved if the workplace and environmental requirements are to be met. It is for this reason that industry must participate in the planning and conduct of Federal research. Thus far, industry has been primarily involved in short-term development of retrofit solutions because compliance with current regulations has taken precedence over longer-term goals and because incentives have been too weak to stimulate research on noise control technology or to encourage purchase of quiet equipment. Both industrial research and demand for quiet machinery could be stimulated by stronger tax incentives. Another strong incentive would be provided by predictable enforcement of regulations and predictable future regulations; in short, less uncertainty about the regulatory environment.

FINDINGS OF THE SURFACE TRANSPORTATION WORKSHOP

In regard to the roles to be played by the private sector and the Government in developing noise-control technology the workshop's consensus was that the Federal Government's role is to identify the need to reduce product noise, to conduct basic research and demonstration programs, and to set required sound levels. Private industry should be primarily involved in achieving the required sound-level reduction. The transfer of research into marketable technology is the province of industry. Government should be involved in basic high-risk new technology rather than incremental improvement of current technology. A minority felt that the Government should be more broadly involved in the entire RD&D chain through basic and applied research as well as demonstrations to the extent that this participation fills gaps left by industrial activity and meets societal needs.

The Federal Government should take the lead in ranking community noise sources and their impact. Purely acoustical descriptors may not be adequate to predict noise impact and further research in this area is needed. Social, psychological, and economic factors must also be considered.

Basic research requiring Government support is called for in regard to diesel engine noise, which may now be at the lowest level possible with today's technology. Fundamental knowledge of combustion processes is likewise needed to establish integrated approaches to the possibly conflicting goal of low noise, fuel economy, and low exhaust emissions.

Basic research is still needed on the mechanism of tire noise generation and on the role of the pavement in producing tire noise. The basic mechanisms of noise generation in the wheel-rail interaction are still only superficially understood with major questions still to be resolved. Because of the diverse elements and organizations involved in tire-road and wheel-rail interaction noise (e.g., pavement, tire, vehicle design and usage, and other related variables), the Federal Government should sponsor coordinated RD&D activities in this area. In furtherance of such a coordinated effort, industry may provide tires, vehicles, and other equipment and facilities as needed. Also in this connection better standard tire test procedures are needed for both on-road and indoor testing. In particular, the procedure described in SAE J57a (1976)[1] should be improved to increase reliability of measurement.

Another consideration is that the Federal Government is preparing to resurface 40,000 miles of interstate and 300,000 miles of State highway. Those RD&D programs necessary to develop a road surface technology that will yield acceptable tire-roadway noise levels while meeting performance and design factors such as skid resistance should be undertaken.

Incentives for noise-control RD&D by equipment manufacturers are provided by the awareness of impending regulations and can be sharpened by better definition of national objectives. On the other hand, regulatory uncertainty can inhibit the development of product lines because manufacturers cannot plan for future years. In some cases industry may halt research for fear that future regulations may make products unsalable.

Educational institutions can play an important role in solving noise problems. They should be training the future noise-control specialists at both the undergraduate and graduate levels. They should perform basic research under both Government and industry auspices. They should be involved in establishing new test methods and can serve as an independent source of data and validation.

Government-supported demonstration programs should provide the basis for the transfer of technology from the research stage to commercial production. They should be so conducted as to demonstrate the practical real-world performance on a production basis of advanced products. Cooperation between Government and industry as in the "Quiet Truck" program is particularly desirable. If demonstration programs require manufacturers' products, the respective manufacturers should be consulted in the selection of representative products.

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[1] SAE J57a (1976) SAE Recommended Practice, Sound Level of Highway Truck Tires, Society of Automotive Engineers, Inc., Warrendale, Pennsylvania, June 1976.

FINDINGS OF THE AVIATION WORKSHOP

Incorporation of noise control considerations in the design of the recently introduced new-generation aircraft to meet Federal regulatory requirements will probably require payload and fuel-efficiency penalties. Technology R&D programs are necessary if future noise reductions are to be achieved without excessive penalties. Basic and applied research advance basic knowledge and understanding. R&D provides the opportunity for technological breakthroughs. It leads to new ideas, technology innovations, advanced design, and predictive methodology.

Engine noise from conventional take-off and landing (CTOL) aircraft is still the principal source of noise impact in the airport community.

Significant reductions in engine noise were made in the past through the introduction of the high bypass ratio turbofan engines and duct acoustic liners to suppress fan tones; the former to reduce jet noise and the latter to reduce fan noise, these being the dominant sources. Future progress in aviation noise reduction will be more difficult to achieve because many noise sources contribute relatively equally to the total noise. Research cannot now be directed at these major sources as in the past but must now be directed at many additional noise sources, for which fundamental understanding is lacking.

A detailed list of research needs was identified, for the two categories of propulsive and nonpropulsive sources. The areas in which research is needed are as follows:

Nonpropulsive

Propagation
Reliable flight data
Validation of design prediction techniques
Development of scaling factors
Airframe

Propulsive

Conventional take-off and landing (CTOL)
Short take-off and landing (STOL)
Supersonic transport (SST)
General aviation
Flow impingement
Rotor and propeller internal and external noise
Gearbox noise prediction
Transmission of noise through fuselages

Identification of a single accepted validated prediction model is of great importance to public officials concerned with land-use planning around airports. More details of and the rationale for these needs are given in section II.C.

The relative roles of the various Federal Agencies, NASA, DOD, FAA, and EPA, with respect to support of the aviation noise effort were reviewed. A larger, long term program of Federal support was judged to be required. The scope and difficulty of the research needs for engine noise reduction alone led to the conclusion by the Workshop that Federal funds for aviation noise RT&D should be increased, and this conclusion extends to other noise sources. It was felt that NASA should have the principal Federal role for supporting noise RT&D, but that there should be another source (FAA) of Federal funding. EPA should retain its coordinating role, while DOD should support basic research.

Any increase in Federal support that occurs should not be for in-house NASA efforts but primarily for grants and contracts outside the Federal Government.

The Federal Government's support should be aimed at long-range research and/or high-risk technology.

Demonstration programs will be required from time to time, but these programs must be carefully selected. They should be conducted to encourage the application of new technology in production aircraft. Prerequisite to conducting any demonstration is the availability of a new technology package. Needs are anticipated for full-scale demonstration of selected propulsion system components for helicopters, general aviation aircraft, and high-speed turboprop aircraft, and mechanical jet noise suppressors for conventional takeoff and landing (CTOL) jet aircraft.

It was felt that product development, proving, and integration of technology into a developing product are the province of industry, which is currently supporting a substantial noise research program at a level equal to that of the government (about 25 million dollars per year--combined Fiscal Year funding and manpower). Industry should have a dominant role in short-term payoff and/or low-risk research, however its participation in noise RT&D and in conduct of the federal R&T program was felt to be essential.

There are a number of pressures other than certification requirements forcing industry to conduct noise R&D and to reduce aircraft noise. These include direct social pressure, competition, airline requests, curfews, and litigation.

A need for the coordination and/or development of national objectives with respect to aviation noise was identified. A clearer statement of objectives is essential to planning of future research programs. A need for one Central Agency to serve as a focal point for bringing together information was cited. Because of its legislative mandate, EPA should lead in coordination of aviation noise research efforts, but because NASA has the principal role in the government for RT&D it should have a part in coordination.

SYMPOSIUM RECOMMENDATIONS FOR NOISE RESEARCH

1. Adequate levels of funding support for research should be provided by the Federal Government to complement private sector efforts in meeting national noise needs. Current levels of Federal funding in the machinery and construction, surface transportation, and aviation areas should be increased to accelerate development of technology to solve stated national noise problems.

2. There are appropriate roles for both the Federal Government and the private sector in noise control research, and their research efforts should complement each other. Industry's efforts should be primarily directed toward the implementation of noise-control technology whereas the Federal Government's efforts should be confined to problem areas in which there is an established need. Efforts of the Federal Government should be directed primarily toward basic research, which provides the basis for new technology.

3. The Federal Government should be involved in long-duration and/or high-risk research. Industry should be involved in short-duration and/or low-risk technology applications for specific configurations. This should not preclude industry involvement in high risk and/or long duration noise research.

4. Another appropriate role for the Federal Government is to support industry in carrying out demonstration programs to test the feasibility of new noise-control concepts. If demonstrations are to accomplish their purpose, they must be conducted in a real-world user environment and must show that the new concepts comply with existing regulations, avoid new hazards, are practical and cost effective, and meet requirements for manufacturability, maintainability, productivity, and reliability. Such demonstration programs can be very helpful in introducing new technology into the market place.

5. The Federal Government should assure continued support for certain needed noise research programs to maintain noise research capabilities. This commitment to continued support should assure the retaining of specialized personnel, research teams, and facilities throughout the Federal Agencies, universities, and in some cases industry.

6. It is important that societal needs and goals (which may become manifest as regulations) be clearly established, that goals whether they are intended to meet health criteria or annoyance criteria have a well established scientific basis. Where necessary, research should be undertaken to establish a scientific basis, and a strategy for meeting these goals be developed. A clear definition of goals should be developed to serve as an incentive for research in noise control technology.

7. EPA should take the lead in coordinating noise research activities among the Federal Agencies, and research plans should be coordinated with industry. The Federal research coordination efforts must take into consideration the need for each of the Federal Agencies to satisfy its own mission mandates. In aviation, NASA should have a coordinating responsibility with EPA. The Federal Government should furnish a single office for exchange and dissemination of information on noise technology research. The private sector should participate in activities (e.g., symposia, workshops, and technical information services) devised to facilitate exchange of information.

8. Educational institutions should be supported in their functions of training personnel and performing basic research funded and guided by government and industry, and providing independent and unbiased consulting service to Government and industry.

9. A long list of noise technology research needs was identified in each of the three workshops: machinery and construction equipment, surface transportation, and aviation. Both the public and private sectors should support and undertake efforts to address these identified needs.

Technology research must be undertaken to address the many noise problems of the industrial sector. Each of the industrial areas represented, identified research needs: Punch presses, forging hammers, large fans, high-speed equipment, textile machines, and rotary equipment are a few randomly selected examples. Because of the large number of research needs requiring attention, priorities for research must be established. There is a great deal of commonality of manufacturing processes and noise generating mechanisms among various industries. In this regard, research efforts have the potential to reduce noise across industry lines.

The principal sources of surface transportation noise are, for the most part common to all vehicles. Three general areas have been identified as having a great impact on surface transportation noise. In this regard, high priority must be given to noise research efforts on:

Diesel engines

Tire and tire-roadway interactions

Rail wheel and track interactions

With respect to the long list of technology research needs developed in the aviation area, it is essential that engine noise receive attention and that its multiplicity of nearly equal noise contributors be addressed if further noise reductions of advanced subsonic conventional take-off and landing (CTOL) aircraft are to be obtained. In addition, if optimum noise and performance considerations are to be effectively incorporated into future aircraft design, then improved and validated component noise prediction methodologies must be developed. These are two of the more important examples of research needs enumerated by the aviation workshop participants.

I. INTRODUCTION

This Symposium was EPA's first response to new Congressional directives in the Quiet Communities Act of 1978 for EPA to engage in and support research in the area of noise-control technology. The goal was to provide a comprehensive assessment of national noise technology research programs and needs from the standpoint of both the public and private sectors. The Symposium focused on noise control research in the areas of machinery and construction equipment, surface transportation, and aviation.

The Symposium was set up specifically to deal with matters pertaining to noise technology research. In this regard, ground rules were established at the inception of the planning stages of the Symposium that specifically excluded other areas such as those relating to regulations and health and welfare with respect to noise.

The defined objectives of the Symposium were:

1. To provide a critical assessment of national noise technology research programs and needs from the perspective of Federal Agencies, State and local governments, manufacturers, users, trade associations, labor, universities, public interest, and foreign interests.
2. To provide guidance to Federal Agencies in planning their noise technology RD&D programs.
3. To develop priority recommendations for Federal noise research.
4. To identify new institutional arrangements for conducting noise RD&D and improving communication between the Federal government and the private sector.
5. To encourage industry to conduct noise technology research programs and to provide guidance with respect to the direction of their programs.

The detailed planning of the Symposium was performed jointly by EPA and a Project Advisory Committee (PAC) and three supporting panels, representing private sector interests as well as Federal Agencies and Departments. EPA's role in the Symposium was that of project instigator and provider of management, guidance, and resources to conduct the Symposium. In every instance, the advice of the members of the Project Advisory Committee was sought.

Participants in the Symposium represented a broad spectrum of private sector interests, as well as foreign interests. Those invited to participate represented: Federal Agencies and Departments, State and local governments, industrial manufacturers and users, trade associations, acoustical consultants, labor unions, public interest groups, universities, and foreign interests. Participants from the following countries attended: Canada, England, France, West Germany, and Sweden. The professional backgrounds of the participants covered many fields of engineering and science. The participants were drawn from technical, policy, and management levels.

The Federal Agencies and Departments which participated in the Symposium are identified below:

MACHINERY & CONSTRUCTION EQUIPMENT WORKSHOP

- Department of the Interior
  - Bureau of Mines (BOM)
- Health, Education and Welfare
  - National Institute for Occupational Safety & Health (NIOSH)
- Department of Defense
  - Army, Navy
- Department of Labor
  - Occupational Safety and Health Administration (OSHA)
  - Mine Safety and Health Administration (MSHA)
- National Science Foundation (NSF)
- National Aeronautics and Space Administration (NASA)

SURFACE TRANSPORTATION WORKSHOP

- Department of Transportation
  - Urban Mass Transit Administration (UMTA)
  - Federal Highway Administration (FHWA)
  - Federal Railway Administration (FRA)
- Department of Defense
  - Army Tank & Automotive Command

AVIATION WORKSHOP

National Aeronautics & Space Administration
(NASA)

Department of Transportation
Federal Aviation Administration (FAA)

Department of Defense
Army, Navy, Air Force

Three workshops were established to deal with noise control research in each of the three areas: machinery and construction equipment, surface transportation, and aviation. These workshops functioned concurrently. To facilitate functioning with a very large number of people and to direct attention to critical areas of interest each of the workshops was subdivided into subgroups:

Machinery and Construction

- Primary metals, fabricated metals, machinery, and transportation equipment
- Lumber, wood, furniture, and paper
- Chemicals, petroleum, and electric utility
- Food, tobacco, and glass
- Textile and printing
- Underground mining and surface processing plants
- Surface mining and construction.

Surface Transportation

- Exterior sound propagation in the community and vehicle interior noise
- Engines and propulsion systems
- Intake, exhaust, cooling and allied engine subsystems
- Interaction of tire-roadway and wheel-rail.

Aviation

- Airframe
- Rotors and propellers
- Propagation
- Engines.

The mechanics of the Symposium are suggested by the program agendas that were used (see Appendix C). Briefly, the manner of proceeding was:

> The keynote addresses at the initial plenary session set the stage and proper tone of the Symposium. Views on the noise control program were given by representatives of the executive and legislative branches of the Government and information in foreign noise research efforts was also presented. The three workshops then met separately. Representatives from the Federal Agencies presented their noise control programs to the workshop covering their area of research. The aviation workshop then heard addresses by some of their subgroup leaders giving background discussions of the status of aviation noise control programs. The other workshops heard addresses by some of their subgroup leaders on conceptual approaches to the issues to be reviewed in depth the following day. The participants spent the second day of the Symposium entirely within the workshops and addressed the discussion issues. The third and final day was used to summarize and develop a final statement on each workshop's activities. These statements were presented before the entire body in the closing plenary session.

The discussion issues dealt with by each of the workshops were relatively similar. Some differences on the issues between workshops were necessary to accommodate the specific needs and interests of each area. The issues for each workshop are identified in Appendix D. Generally, the issues dealt with the current status of noise control technology, future research needs, and the appropriate roles to be played by the Federal and private sectors. With respect to the issues addressed, the aviation workshop had the greatest differences, considering such subissues as: whether the Federal noise research program was properly balanced between the various elements of RD&D; and whether the Federal program should be induced to put risk capital into noise research.

II. SYMPOSIUM RESULTS

IIA. MACHINERY AND CONSTRUCTION EQUIPMENT WORKSHOP RESPONSES TO ISSUES

The Machinery and Construction Equipment Workshop found it necessary to define specific noise goals to which noise control research needs could be related. In this regard, the workshop assumed for the purposes of discussion, an A-weighted sound level of 90 dB as a goal for an 8-hour exposure in the workplace. No specific criterion was assumed for environmental noise, and as a result the treatment of this subject was more general. It should be understood that the responses of the workshop would vary with changes in assumed goal and that the assumption of a goal does not constitute an endorsement in any sense by anyone present at the meeting or by any organization represented at the meeting.

1. What is the status of noise control technology?

OVERVIEW

The issue of the status of noise control technology was approached in part by considering the availability of and needs for both source and retrofit controls.

Few source controls for industrial equipment with applicability across product and process lines were found to be available. Source controls were, for the most part, felt to be the optimum long-term approach necessary for reducing noise. They are usually associated with lower total costs (i.e., implementation, maintenance, and productivity) than retrofit. Source controls are usually implemented during new product design. The retrofit approach to reducing equipment noise is usually less than optimum because of the higher long-term cost required to implement it. For example, many retrofits must be done repeatedly because they are temporary "fixes." With respect to noise, a major problem facing American industry today is the availability of control technology that falls within the economic bounds required by profit-making firms.

Some technology, for the most part retrofit, does exist in areas to reduce and control both occupational and environmental noise and is both technologically and economically feasible. However, there are many products and processes for which acceptable control methods are not available. At present there are, according to EPA estimates, some 3.5 million Americans working in environments where levels exceed DOL workplace noise-exposure requirements. EPA estimates also show that there are some 13.5 million Americans working in noise environments sufficient to cause some hearing loss.

Technology research is one approach to developing technologically and economically acceptable methods for noise control.

1.a. What major noise-related research programs does industry (corporations and trade associations) have underway?*

Very few programs were identified within the private sector that are focused on research, design, and demonstration of source noise controls. Due to competitive proprietary needs as well as information transfer constraints imposed by anti-trust restrictions, identification of industrial noise-control research is difficult. There are retrofit programs underway in most industries, and current efforts are for the most part directed at retrofit. Trade associations, industrial manufacturers, industrial users, consulting firms, research institutes, and universities are conducting the private-sector projects underway.

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*Federal noise control research programs have been identified in the report published by the Federal Interagency Machinery and Construction Panel (refer to the Introduction), Federal Research, Development, and Demonstration Programs in Machinery and Construction Noise, EPA 550/9-78-306, U.S. Environmental Protection Agency, Washington, D.C., February 1978.

The following industry noise-control research projects and/or organizations supporting noise research were identified:

Sponsor	Technology Area	Research Organization
Aluminum Association Inc.	Saws	University of Wisconsin
American Foundryman's Society	Burners, furnaces, grinders, chippers, shakeout, jolt and squeeze devices	
American Iron and Steel Institute	Rolling mills, furnaces (electric arc, burner)	H. L. Blachford
Forging Industry Educational Research Foundation	Forging burners	Michigan Technological University
Industrial Fasteners Institute	22 pieces of equipment (cold headers, swaggers, out formers, pointers)	H. L. Blachford
Glass Packaging Institute	Closures	North Carolina State
Organization Resources Inc.	Punch presses	
Canners League of California		
Northwest Food Processors Association		Bolt Beranek and Newman, Inc.
Chocolate Manufacturers Association		Bolt Beranek and Newman, Inc.
North Carolina Dairy Producers		North Carolina State
American Bakers Association		

Sponsor	Technology Area	Research Organization
Textile Industry	Textile machinery	Unidentified equipment user and several machinery manufacturers
Underground Mining Industry	Mining equipment	Several manufacturers and users
American Mining Congress (AMC)	Mining equipment	Task group being formed
Surface Mining Industry	Mining and construction equipment	Several manufacturers

1.b. What are the principal approaches available to reduce equipment and process noise?

Approaches available to reduce equipment and process noise depend very much on whether the equipment is in the conceptual and/or design stage of its development or whether the equipment has been fully designed into a marketable product and is ready to be or has already been installed for field use.

For a number of reasons, source controls are for the most part restricted to the conceptual and design stage of equipment development. The consensus was that few source controls are available, although they would be the most acceptable and economical long-term solutions.

Retrofit controls (such as enclosures) for the most part embody approaches that in some cases can be adapted to equipment and processes already developed and can be adapted to new equipment in development. Retrofit approaches to reducing equipment and process noise are the principal approaches currently available and utilized to reduce noise. These approaches involve:

Enclosures of employees and/or equipment

Substitution of equipment and process

Equipment, process, plant layout

Barriers

Vibration damping materials

Equipment and process redesign

Material changes

Vibration isolation (limited retrofit applications)

1.c. What are some of the major types of equipment and processes for which noise control methods are unavailable?

A list of specific items of equipment was developed for which acceptable source control solutions were unavailable and for which technology research, development, and demonstration efforts were necessary (refer to Table 2.1). Entries on this list should not be considered all inclusive. Also, inclusion on this list does not necessarily mean that some controls, at least through retrofit, are not already available. With respect to processes (involving assemblage of many or special equipments) noise control techniques are often unavailable. It should be noted that the availability of technology does not in itself mean that adequate incentives exist for its implementation (refer to issue 3).

TABLE 2.1. MAJOR TYPES OF EQUIPMENT AND PROCESSES FOR WHICH FURTHER NOISE SOURCE CONTROL RESEARCH, DEVELOPMENT, AND DEMONSTRATION EFFORTS ARE NECESSARY*

a. Metals/Fabrication Equipment and Processes

- **Mechanical power press/shear
- **Saws
- **Hand tools (electric and pneumatic, grinders, chippers, scaling, jackhammer)
- **Metal Removal
- **Forge hammers
- Cold headers
- Swaggers
- Nut formers
- Pointers (metal removal)
- Shake-out
- Jolt and squeeze
- Air arc gouging
- Burner/furnaces
- Electric arc furnaces
- Material-handling systems
- Plasma spraying
- Riveters
- Rolling mills
- Rotary scrap choppers
- Shredding
- Scarfers
- Spray guns
- Air conveyors
- Chutes
- Sand blasting
- Torch solder gun
- Welders

b. Wood/Lumber/Paper Equipment and Processes

Sawmill

- Planer-matchers
- Head rigs

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*Please refer to paragraph 1.c. for an explanation of the applicability of this list.

**Highest priority within this subgroup

Sawmill (continued)

Edgers
Trim saws
Ripsaws
Sanders
Conveyors
Chippers

Moulding

Moulders
Cut off saws
Rip saws
Chippers

Paper

Machine rooms
Corrugators
Pumps
Grinders
Saws
Chippers

Furniture

Rough planers
Cutoff saws
Rip saws
Surfacers
Moulders
Tenoners
Shapers
Routers
Carvers
Chippers

Plywood

Lathes
Clippers
Stackers
Trim saws
Chippers

c. Chemical/Petroleum/Electric Utility Equipment and Processes

Centrifugal compressors
Multi-stage centrifugal compressors
Gear boxes
Burners
Gas turbines
Very large fans
Rotating equipment air cooling systems
Fluid control valves
Internal combustion engines
Size reduction equipment
Positive displacement pumps

d. Food/Tobacco/Glass Equipment and Processes

Food

Container contact
High-speed rotating machinery
Product mixing and shredding
Weiner peelers
Dough preparation mills
Extension equipment

Tobacco

Making machines
Tippers
Packers
Packaging

Tobacco (continued)

- Leaf stemming lines
- Vacuum conveying
- Air ejection
- Dust collectors
- Product impingement
- Wet machines
- Dryers

Glass

- Cooling air equipment

e. Textile/Printing Equipment and Processes

Textile

- Looms (rapier, fly shuttle, projectile and jet)
- Ring spinning
- Texturing
- Spin-draw
- Twisting
- Winding
- Coning
- Knitting

Printing

- Rotary presses of all types
- Folders
- Air-operated scrap removal systems
- Drive trains

f. Underground Mining/Surface Processing Plants Equipment and Processes

(A relatively long list of equipment used in underground and surface processing plant operations could be developed from the basic processes listed below.)

Extractive equipment such as cutting machines
Percussive equipment
Impact devices
Coal and rock preparation: crushing, screening,
  and other preparation processes
Internal combustion engine

g. Construction/Surface Mining Equipment and Processes

Work-tool interface (rock bit striking rock)
Internal combustion engine (diesel and gasoline)
Back-up and forward warning alarms

1.d. Has there been noise abatement technology transference from one product/process to another?

In general, retrofit solutions for noise control are transferable and have been transferred from industry to industry. Enclosures, for example, have found wide application but only as a general concept, for the particular requirements of specific workplaces vary enormously.

There is a great deal of commonality among machines and manufacturing processes with respect to basic mechanical movements and mechanisms. In this regard, technology to reduce noise at its source is readily transferred across equipment and manufacturing process lines. However, installation factors (e.g., pipes, supports, and ducts) are not common, even in the same plant location, with respect to noise radiation. Impact noise reduction is an example wherein knowledge of how to control a given source can affect many equipments and processes.

The fact that little source control transference has occurred is due principally to the high degree of unavailability of source controls. The inability of individual industrial corporations to divulge their manufacturing technology developments because of anti-trust restrictions as well as competitive market pressures to some degree inhibits technology transfer.

1.e. What research should be done?

In the response to prior issue 1.c. a long list of equipment was identified for which source controls were unavailable and for which research was necessary. Some of the variables that should be considered in establishing priorities were identified. These variables are also contained in the answers to issues 2.a, 2.b, 2.e, 3.c, and 3.d. A list of perhaps ten high-priority needs should be identified and developed. The following factors were identified as ones that might be considered when establishing research priorities:

Final levels of allowable exposure promulgated by the Department of Labor/Occupational Safety and Health Administration (OSHA) in the workplace noise standard

Final equipment noise and labeling regulations promulgated by the Environmental Protection Administration (EPA)

Ability of industry to implement noise controls

Extent and seriousness of the impact of given equipment and processes on the health and welfare of the general- and workplace-population (e.g., number of people over-exposed, extent of over-exposure, and number of pieces of equipment

Willingness of the Federal Government, original equipment manufacturer, and equipment users to assist with a specific machine.

In reviewing this issue it was felt that research efforts should, in most cases, be followed through from the beginning in the laboratory (development of basic understanding) through to demonstration of the end product. The importance of industry participation in demonstrations was emphasized. It should be noted again that an A-weighted sound level of 90 dB as a long-term goal for research was assumed for the purposes of the workshop.

2. What role should the Federal Government play in developing noise control technology?

OVERVIEW

All industrial subgroups identified the need for limited Federal Government involvement in machinery and construction equipment noise control RD&D. [Refer also to the "General" response to issue 3.] All subgroups concluded that some products and processes in their industries required Federal support of research. Any activities undertaken by the Federal Government, however, must be directed at filling well-defined needs; and criteria for need should be defined as they were in this symposium (e.g., degree of risk of hearing impairment, number of people exposed, availability of control technology, and rate of progress by industry).

Any activities undertaken by the Federal Government should complement those of the private sector. Federal activities should include: support of basic research (high risk), applied research, demonstration projects; establishing a climate or incentives (such as tax) for support of noise control RD&D by the private sector, coordination of Federal research with the private sector. More specifically, the Federal effort should complement the private effort by doing primarily high risk research that needs to be done when the private sector is unwilling or unable to do it. High risk basic research is an area in which industry is seldom able to invest the required long-term resources.

Definitions that generally distinguish between basic research and applied research are difficult to establish, for what is one person's basic research is frequently another's applied research. Thus, no attempt is made to identify clearly the views of the participants as related to basic or applied research.

Lack of basic knowledge is currently a serious impediment to developing source noise control technology. Each of the industry group reports agreed that a major role of the Federal Government is to support research that will advance basic knowledge and develop expertise.

Coordination. There was a general consensus that there was a need for coordinating the research activities within the Federal Government as well as coordinating between the Federal and private sectors. It was felt one focal point should exist within the Federal Government to support coordination. The need for private sector participation and input into the conduct and planning of the Federal research programs was defined.

Demonstration Projects. There was general agreement that there should be Federal support of demonstration projects, although there were differences among the industry groups in the level of effort judged to be necessary. Some of the industry groups felt a significantly stronger Federal effort was required in research than in demonstration. One factor that undoubtedly influences the need for demonstration projects is the adequacy of available technology. If there is little available technology, Federal efforts will be better directed to research to further the development of basic knowledge that will later support the development of technology. Industry's involvement in any Federal efforts to demonstrate noise control technology is defined as essential.

General. The Federal Government should stimulate industrial involvement in noise control research by offering tax incentives and by paying premium prices for quieted goods when private-sector demand might not in itself be a sufficient forcing factor. Occupational and environmental Federal regulations place uniform demands on an entire industry and are a driving force for research in the private sector. Noise goals can also impel research when they are practical and properly defined with respect to time. Federal labeling requirements could serve as inducements to industrial manufacturers to reduce product noise and spur necessary research.

A minority view offered by some of the Federal representatives was that some Federal Agencies, such as DOD and DOI may have Legislative Mandates that require them to undertake specific noise research to meet their own mandated needs rather than "National" needs.

2.a. What factors should influence Federal involvement in noise research?

The general view was that the role of the Federal Government in developing noise technology should be limited in the sense that program efforts in noise control research must be focused on societal needs and directed at high need, high priority areas. Federal programs should emphasize relatively high risk long-term research problems, those with low probability of immediate return on investment and leave product design to the private sector.

A number of factors were identified that should influence Federal efforts:

> Degree of risk of hearing impairment. This factor will be a function of both severity of exposure and number of people exposed. Workmen's compensation claims for hearing impairment could be one measure of risk. This factor also interacts with other health and safety hazards.
>
> Anticipated benefits. For example, areas in which the greatest reduction in potential for hearing impairment can be achieved should receive the highest priority--a "worst first" priority.
>
> Availability of basic knowledge of noise control, availability of noise control technology, incentives probability of immediate success in finding a suitable technology, extent of private involvement already present and the rate of progress toward a solution, and the ability (or need for support) and willingness of the private sector to solve a problem. Lack of any of these factors was identified as establishing a need for Federal involvement. Research in areas where essential basic knowledge does not exist, where noise control technology does not exist, and where the probability of immediate success is low all might be called high risk research, that is, any return on funds invested in research will be relatively far in the future if at all.
>
> Highly fragmented industries. In many instances such industries may not be able to muster sufficient resources even for product development, so some support may be needed outside of the high-risk area. On the other hand, there may be areas in which there should be some combined investment, for example, joint support might be given to a project begun by a trade association. In general, Federal efforts should complement, not duplicate, private efforts.

2.b. For what products, processes, and industries should the Federal Government be undertaking noise research?

Factors influencing where Federal support for noise control RD&D should be directed were identified in the response to issues 2.a. and 1.e. Some specific types of equipment and processes for which noise control methods were unavailable were identified in the response to issue 1.c. Other types of equipment and processes for which noise control methods are available but, for one reason or another, are unacceptable could be listed, but these types should be assigned a lower priority. All of the industrial subgroups concluded in their summaries that some products and processes in their respective industries required some Federal undertaking of research. Each of the groups indicated that an essential role to be played by the Federal Government was to support research that would advance basic knowledge and lead to the development of noise control technology and expertise.

2.c. What other areas of noise generation should receive Federal research support?

In addition to the products and processes indicated by the answer to issue 2.b it was felt research attention should be directed at the basic sources of noise as well as controls common to many different products and processes:

Basic Noise Sources

High-speed rotary systems that transfer energy or materials

Combustion

Fluid moving systems

Process fluid control systems

Material cutting

Material forming

Power transmission

Bearings

Belts

Impact-impulse

Noise Control Factors

New process technology with inherently lower noise such as in mining equipment

Materials used for noise control.

2.d. What future technology developments will influence noise control and/or research?

Three developments appeared to have the most general application. Automation and computer control will allow remote location of operators, but maintenance crews will remain in the noise fields. The shift in dependence on, as well as development of, new energy sources may well introduce noise-control problems that will have to be addressed. For instance, much of the equipment used in surface and underground mining produces noise levels potentially harmful to hearing.

2.e. What balance should be given to support for demonstration programs and research to develop new technology?

On the whole, development of new technology, research, and demonstration received about equal emphasis. One industry group felt, at the beginning of its session, that there should be no Federal support for demonstration programs but later changed its position to recommend jointly sponsored programs--industry would supply facilities and workers and Government would supply technical support. Another felt that demonstrations should receive more emphasis than research. These differences seem to reflect some differences in the status of noise-control technology among industry groups. In other words, Federal resources need to be directed to development of technology if there is little in the way of technology to demonstrate. In general, it can be said that relative emphasis should depend on the current state of noise control technology in a particular industry and that the emphasis should shift from development of technology to demonstration of technology as progress is made.

3. What role should the private sector play in developing noise control technology?

OVERVIEW

The general response to this question was that industry must furnish the direction for development of noise control technology. Goals have been set by the EPA* and workplace and environmental regulations have been set by the DOL and EPA respectively; but the direction for research needs to come from the private sector (industry, university) because it possesses detailed knowledge of what problems must be solved for the goals to be achieved. Thus, industry must have, in this sense, a leading role if meaningful and timely research is to be conducted. Although industry participation will depend on its assessment of the incentives, industry feels strongly that it can contribute to basic research, product development, and demonstration projects.

From the point of view of the private sector the motive force for noise control is incentive. Without incentives, both positive and negative, there can be no technological development, and present incentives for noise control are weak, absent, or uncertain. Current incentives produce the current level of research, and the level of effort will adjust to changes in them.

It should also be pointed out that many small manufacturers do not have the resources to carry out product development research even if generous incentives were to become available to them.

3.a. Can industry solve the noise problems without input and assistance of the Federal Government?

There was no consensus on this subissue. Generally, industry expressed confidence that they could solve the problem provided that the proper economic incentives were available. However, many of the smaller manufacturers felt that they did not possess the necessary resources, nor could they justify the investment without the definite assurance of a satisfactory return. Some of the smaller manufacturers felt that almost under no circumstances could they devote resources to noise control. Other negative responses cited the inability of industry to justify the allocation of the necessary resources to noise research because of current market demands. Also in research areas where full public disclosure is desired, conduct of research by the Federal Government was preferred to avoid conflict with anti-trust laws.

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*Toward a National Strategy for Noise Control, U.S. Government Printing Office 720-117/1999, U.S. Environmental Protection Agency, Washington, D.C., April 1977.

3.b. What are the incentives for noise control RD&D by equipment "manufacturers" and "users"?

Incentives have been classified according to whether they affect equipment manufacturer or equipment user, and according to whether they presently exist in the economic system or are needed and could potentially exist. Present incentives were identified as, in general, relatively weak, though their strength varied greatly from group to group and from product to product. Present economic incentives define what research will take place on the basis of supply and demand. With respect to retrofit noise controls, negative incentives presently exist for its implementation.

MANUFACTURER

Present Incentives

Competition with both domestic and foreign manufacturers to improve or at least maintain market position is a strong incentive.

Profit motive is an essential incentive. The equipment manufacturers stated that they could not invest in developing quieter equipment until there was an adequate market and/or until noise was a strong selling factor. Many of the users, however, countered by saying that a market was available because they would pay more for quieter industrial equipment if it were available.

Equipment purchase specifications specifying noise requirements were cited as an area that has not been fully utilized as much as it could. It represents customer pressure and forces market demand. It was suggested that the Federal Government through its purchasing power play a role in forcing market demand by specifying quiet equipment. GSA was one Federal Agency noted that could play a role through purchasing and specifications.

Present and anticipated product noise regulations, both domestic and foreign, were cited as potentially powerful incentives. They have been little used; but their use is growing, and many manufacturers are attempting to anticipate future regulations.

Potential Incentives

Tax incentives to invest in research and development of quieter products would allow a stronger case to be made for investment to meet an anticipated future demand. Some preference was expressed for tax incentives over direct government contracts. However, the ability to use tax incentives were correlated to some degree to the size of the manufacturer (refer to the Overview to issue 3 on the previous page). The smaller manufacturer might not be able to respond, even given these incentives, and he may not be able to bid on government contracts, as well.

Decreased cost of product liability claims to the equipment manufacturer for hearing loss.

EQUIPMENT USER

Present Incentives

Compliance with the Federally imposed DOL workplace noise standards as well as local ordinances is the strongest and most immediate incentive. At present there is more of an incentive for development and implementation of retrofit solutions than for research to develop source controls. Primarily variability of enforcement and to a lesser extent uncertainty of future standards have made this incentive compliance with standards much weaker than it might otherwise be. Current uncertainty with respect to future limits of the DOL/OSHA workplace noise standard were cited as an inhibiting factor.

Concern for the health, safety, and welfare of workers through the reduction of noise hazardous to hearing.

Potential Incentives

Decreased costs from workman's compensation claims and maintaining hearing-conversation programs.

Increased productivity resulting from working in an area with an optimum environment.

Tax credits for buying relatively quiet products.

3.c. In what specific areas should noise control research be done by private industry?

The general response to the question was that private industry must take the dominant, leading role if, in fact, meaningful and timely research is to be conducted. It was emphasized that industry's involvement is not limited to a particular area such as basic research or applied research or demonstration but, rather, it encompasses all research areas. All subgroups, however, clearly identified one area--that of applications research or more appropriately product development. By necessity this approach must be taken by industry whenever proprietary developments--either products or processes--are involved. Product development requires long-term research efforts involving significant changes in product lines.

3.d. What are the constraints that inhibit development of noise control technology by industry?

In general, absence of the incentives discussed under subissue 3.b. inhibit development. Other inhibitors were identified and further elaboration on some of the incentives discussed under subissue 3.b. was developed.

There is a lack of basic knowledge, as discussed under Issue 1, and there is a lack of expertise to apply what knowledge there is.

There is a lack of research facilities, and insufficient money has been allocated by industry to do research in existing facilities. There are several closely related reasons for this circumstance. On the one hand, other environmental, health and safety problems are competing for research money, and, on the other, there is great variability in the enforcement of noise regulations. Further, noise is not a life-threatening occupational hazard. All of these factors sum to a low priority rating when research money is being allocated.

There are also legal constraints that act to inhibit development. Industry can be reluctant to demonstrate new technology for fear that regulatory agencies will consider it a generally "feasible control." Exchange of information about noise control technology is also inhibited by fear of restraint-of-trade provisions in anti-trust law. This factor reinforces the inhibitory effect of competition on exchange of information. These legal and competitive restraints suggest that the government can have a stimulative role in joint demonstration projects and exchange of information about the technology used in them. Emphasis on retrofit under enforcement of current regulations diverts funding from research to fixes.

3.e. What role should educational institutions play in RD&D for the industrial, and machinery and construction equipment areas?

Universities should be a source of educated professionals having an engineering and scientific training in acoustics; and should engage in research, development, and demonstration activities, with principal efforts centered on basic research. There was some discussion on whether there was currently an adequate number of college trained professionals in acoustics to solve the technology problems that had to be addressed, but no consensus was reached on this point. With respect to the RD&D process, there was no consensus with respect to the full role that had to be played by the university. There was a clear consensus, however, that the university should be a resource for undertaking basic research, principally long term. Some sentiment was also expressed by industry for university involvement in the development and demonstration phases of the RD&D process partly because they would serve to provide the training that industry requires and needs. There was general agreement that uncertainty in goals and in funding university research has a detrimental effect on both the research and training functions. If universities are to be relied on to develop and maintain noise-control research capabilities, then sustained support is mandatory. The current system used to fund research at universities--which is fragmented at best--must be improved if they are to be responsive. The remaining question is--Who should provide the funding? There was an indication that industry may be willing to provide some level of support, as it has in the past.

4. How and in which areas can Government and industry work together on noise RD&D programs?

There appears to be a general consensus among the participants that:

a. There is a need for Government and industry to work together on basic noise research.

b. Results of the research work should be demonstrated on projects to provide a means to disseminate the information to all interested parties on a regular, periodic basis. It was also felt that there should be joint participation in the process of identifying needs for research projects and settling of goals and objectives for them. The thought was also expressed that while noise research may well be necessary it would be insufficient by itself to abate noise.

4.a. What method/procedures can be utilized to disseminate and implement the results of successful RD&D programs?

a. The answers the various groups developed to this question ranged over the numerous existing channels of communication to include regular dissemination of printed reports, presentations of technical papers in technical society meetings, publications of articles in trade journals, advertising the availability of such information in the press, presentation of work in workshops and symposia convened for this specific purpose.

b. The need for informing interested parties of the currently existing sources of such information and how to utilize them was pointed out, and it was indicated that only minimal advantage is being taken of the vast array of information that already exists. The principal reasons that existing information is not being utilized is that the very existence and location of much of it is not widely known. This suggested the need for a single contact point somewhere in the Federal Government where questions concerning noise research can be presented and answers obtained.

c. It was also suggested that trade associations could provide a service to their members by providing noise-research information to them that originates within the Federal Government.

4.b. What specific noise-control demonstration programs would aid equipment manufacturers and users to introduce noise control measures?

a. The combined report from the seven sub-groups resulted in a list of factors that were felt to be essential to the adoption by industry of the results of any demonstration programs. The factors identified, not necessarily in order of importance, are:

(1) Successful demonstration in a user environment of user acceptability.

(2) Cost effectiveness.

(3) Practicability.

(4) Reliability.

(5) Maintainability.

(6) Productivity.

(7) Durability.

(8) Achievement of compliance (with applicable regulations).

(9) Avoidance of any new hazards to health and safety (fire hazard, visibility restrictions, etc.).

In other words for the demonstrated technology to be accepted by industry it must satisfy all of the real-world demands imposed by users in profitable operations.

4.c. What forum or mechanism can be used effectively to provide for an exchange between Government and industry concerning noise research needs and accomplishments?

There seems to be some difficulty in answering this question, perhaps because of its similarity to 4.a.

Among the suggestions for a forum or mechanism were:

> There should be a central source for disseminating information, operating on a regular basis, and producing periodic reports.
>
> There shall be distribution of printed communications containing information from the same central source through publication and trade journals, trade associations, technical societies--both through active participation in committee work by Government people, and through presentation of technical papers and also a suggestion that conference proceedings be made freely available through Government funding.
>
> Finally, a recommendation was made that a steering committee be formed to act as an intermediary through which research needs could be conveyed to EPA and/or the Federal Government; and at the same time noise research accomplishments could be made known and their adoption encouraged by the broad range of interests represented by such a committee. This committee could have representation from across the private sector, particularly the industrial manufacturers, acoustical consultants, labor, and the Federal Government. The desirability of establishing a mechanism for review of progress and difficulties in Federal research programs by the private sector was identified. Meetings including program review sessions could fill this need.
>
> Joint participation by the Government with the private sector in research and demonstration programs would, in itself, serve as an effective mechanism for identifying future research needs to the Government.
>
> Workshops, directed to narrowly defined areas, were identified as an effective and desirable mechanism for defining specific research needs in particular areas.

Adequate non-adversary communication between the Federal Government and the private sector does not presently exist. In this regard, a need for the Government and, in particular, the EPA to encourage two-way communication was identified.

A set of recommendations was developed by the chemical, petroleum, and electric utility subgroup and presented to the plenary session of the Machinery and Construction Equipment Workshop. The recommendations were not adopted by the workshop, so they are given here as a minority opinion at the request of the subgroup. The subgroup recommended:

a. Joint industry, university, and government participation in establishing achievable noise goals

b. Positive marketplace incentives for development and implementation of noise control technology

c. Joint partnership for industry, university, and government in a noise research program, including: goals, budget, and schedule

d. A separate program for fundamental noise research

e. A separate program for determining the effectiveness of a research and implementation program

f. A separate program for assembling and disseminating results.

IIB. SURFACE TRANSPORTATION WORKSHOP
RESPONSES TO ISSUES

1. What is the status of noise control technology?

1.a. What are some of the major types of equipment for which noise control methods are unavailable?

The principal noise sources for all surface transportation vehicles (highway, off-road, rail) are for the most part common to all vehicles and can be readily grouped into just a few classifications as shown here:

Internal combustion engines (diesel and gasoline)

Power system drive trains

Principal engine subsystem components such as intake, exhaust, cooling, and allied subsystems

Tire and roadway, and their interactions

Rail wheel and track, and their interactions.

The presentation which follows is, as far as possible, in terms of these classifications. In general, some technology is available for controlling noise at its source for each of the components of surface transportation vehicles.

The internal combustion engine is a universal powerplant for surface transportation vehicles. Due in part to fuel economy needs, the use of the diesel engine, particularly for automobiles, is expected to increase in the coming years. The current diesel engine is noisier than its counterpart, the gasoline engine. Knowledge on how to reduce the noise of the internal combustion engine through fundamental design is limited.

Tire noise originates from a complex interaction of the tire with the road surface. Although significant work has been performed in recent years in an effort to understand the mechanisms of noise generation associated with this interaction, these mechanisms are not well understood. Without an increased understanding of the noise-generation mechanisms, current technology does not appear to permit further noise reductions of any significant amount. The current-generation quieter tires are at the minimum noise levels that can be achieved by current knowledge.

The noise generated from the wheel/rail interaction can be categorized into three groupings: wheel squeal at curves and railroad retarders, impact noise, and roar noise. Knowledge of the basic mechanisms of noise generation for each of these categories is only superficial and as a result there are no adequate methods of noise control.

1.b. What are the principal approaches available to reduce equipment noise?

Standard acoustical techniques such as use of enclosures, vibration isolation, damping, muffling, redesign of components, etc., are available. It is possible to eliminate a noise source through redesign of the system (one example is the use of demand-actuated cooling fans).

Based on the limited understanding of the wheel/rail interaction, attenuation measures presently used are not ideal solutions. Some noise control measures in use are lubrication, resilient wheels, damping for rail squeal at curves, ramp control and alternate brake-shoe material, continuous welded rail, wheel truing and rail grinding.

With respect to available approaches for reducing the annoyance of tire noise, a minority opinion was that the frequency spectrum of the noise generated by the tire could be altered.

1.c. What noise-related research programs does industry (corporations and trade associations) have underway?

Noise-technology research programs have been conducted in all areas by one or another company. No specific noise-related programs being conducted by corporations and trade associations were identified. For proprietary reasons, noise research programs of corporations could not be identified.

Some examples of research programs that were identified in general terms are as follows:

> "Acoustical Intensity Technique," a new approach for component noise source identification--to be published soon by the Society of Automotive Engineers (SAE).
>
> Community noise source descriptors, all-weather test facility, environmental effects on noise measurement, correlation of bare engine to complete truck noise levels, variability of noise measurements, roadside surveys for long-term noise-level changes are typical of industry joint efforts.

1.d. Has there been noise-abatement technology transference from one product/process to another?

There have been many cases of technology transference in the field of surface transportation noise control. Some examples of such transference are cited here:

> Application of cooling-system noise-control technology across all vehicle types
>
> Mufflers from trucks to locomotives
>
> Engines, tires, mufflers from trucks to buses.
>
> Rail/wheel technology has benefited from the transfer of FHWA work on ground vibration isolation and from industrial work on structural damping techniques, vibration isolation, noise diagnosis, and noise source identification.
>
> Some comments regarding technology transference are:
>
> Noise-technology transfer on an intracompany basis is generally effective. Company-to-company transfer is slower and limited to review of formal reports for the most part. Applied research by companies is not usually transferred for proprietary and/or antitrust reasons.
>
> Basic research would be readily transferable on a broad basis, but not much is available.

Technical societies provide effective means for communicating technology developments.

Applicability of a transfer of technology must be validated in demonstration projects if it is to be accepted.

1.e. What are the noise-control research needs?

Concerns for achieving improved fuel economy, reduced emissions, and reduced noise from internal combustion engine operations point to a need for fundamental research on combustion processes and integrated approaches to meet these concurrent needs.

For the most part noise-control research needs center on controlling noise at the source. This requires an improved basic understanding of noise-generation mechanisms. Areas in which this research is needed are discussed in the following paragraphs.*

Internal Combustion Engines (Diesel) and Power System Drive Trains

A better understanding of noise generation and propagation through or from the engine and drive train that can be applied to the design process from inception, is needed:

> The phenomenon of diesel engine block ringing due to the combustion process is not well enough understood and requires more investigation.
>
> Mechanical noise resulting from the moving parts of the engine has been investigated but more work needs to be done in the actual application of theoretical solutions.
>
> More investigation needs to be done in the use of isolation mounting techniques to control re-radiation of engine noise through the vehicle frame and panels.

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*It was pointed out that, owing to the relatively short time that was available to the Symposium participants to discuss and review the issues, it was not possible to develop a truly comprehensive list of noise-control research needs.

Intake, Exhaust, and Allied Subsystem Noise Control

Better understanding of intake, exhaust, and allied subcomponents is required as listed below:

Basic*

Source, radiation and perforation impedances for exhaust attenuators

Non-linear effects of exhaust noise attenuators (mufflers)

- large-amplitude waves
- flow effects
- temperature gradients

Higher order modes of resonance of flow-generated noise in exhaust systems and intake systems

Applied

Measurement techniques
Vibration isolation between engine and exhaust
Source characterization
Effect of catalytic converters
New materials (acoustical and structural)
Water injection into exhaust gases
System modeling (acoustics and fluids)
Packaging to lower volume
Back pressure
Inlet restriction
Weight reduction
Shell noise of mufflers

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*Note: theoretical and experimental work required in all basic research areas.

Cooling System (Fans) Research

Cooling system research needs are listed below:

Basic*

Fan-noise mechanisms

- tip effects
- separation
- flow noise

Fluid mechanics of fan
Heat-rejection mechanism (engines)

Applied

Systems approach to heat transfer (match fans, radiators, pumps, etc.)

Cooling system design based on results of new basic research

Alternate configurations such as centrifugal fans, natural convection radiators, etc.

Pitch control of fans
Heat storage
Cooling-fin damping and design

Auxiliary Equipment Research

Hydraulic fluid and structure-borne sound transmission need to be studied.

Tire and Roadway Interactions

With current tire-roadway noise technology there appears to be a "noise floor." Basic research needs to be done to determine whether this "noise floor" really exists. In order to realize the full benefits of further research and development to reduce engine noise, tire/road noise reductions must be advanced concurrently, or else total vehicle in program noise reduction will, in general, remain unaffected.

If the apparent lower limit for tire noise is to be lowered, it can only be reduced by conducting basic research into the mechanisms of tire-noise generation. Factors such as life-cycle cost, traction, rolling resistance, wear, tire use, and manufacturing methodology are variables with which noise-technology research must be integrated.

Although the road surface is an equally important factor in the generation of tire-roadway interaction noise, it is typically excluded from consideration during roadway design and selection of pavement surfaces and finishes, partly because of limited knowledge of the causes and methods of reducing tire-road interaction noise. Factors that need to be integrated are: roadway surface materials, surface texture, skid resistance, and roadway design.

In the near future the resurfacing of some 40,000 miles of the interstate Federal highway system and 300,000 miles of state highway will be undertaken. All available technology for reducing tire-roadway interaction noise need to be brought into play in that effort. It should be a relatively high priority area for further research so that noise-control technology can be developed and introduced in timely fashion.

Current methods for measuring noise from tires and their interactions with roadway pavement for both outdoor and indoor test conditions are inadequate. The widely used Society of Automotive Engineers (SAE) test procedure J57a "Recommended Practice, Sound Level of Highway Truck Tires," for example, needs to be improved with respect to the accuracy and precision it allows. The accuracy and precision of the various tire laboratory noise-test facilities are unknown as well as the correlation between laboratory and field measurements.

Rail Wheel and Track Interactions

Some specific research needs for the problem of rail wheel and track interaction generated noise (wheel squeal at curves, railroad retarders, impact noise, roar noise) are:

Alternative rail-joining techniques

Criteria for determining when wheel turning and/or rail grinding are required

Rail grinding techniques

An understanding of the causes of rail corrugation and methods of preventing wheel flats

Materials, e.g., high-energy-dissipative structural materials and vibration-damping materials

Materials

There is a need for new and improved materials for noise control. Currently available materials used in controlling noise have limitations with respect to such factors as cost, durability for extended use, flammability, acoustic effectiveness, adaptability and effectiveness in environmental extremes.

2. What role should the Federal Government play in developing noise-control technology?

2.a. What factors should influence Federal involvement in noise research?

The Federal Government should be involved in basic high-risk new technology research rather than low-risk research that could or would be done by industry.

Current Federal program funding for surface transportation noise-control projects is low when contrasted with its total public impact.

Factors that should influence Federal involvement are:

Societal needs that require an accelerated noise reduction program or quieter product that will not be brought about by normal market forces and industry.

Ability and incentives for industry to meet and adopt to technology needs. Marginal industries have fiscal constraints that meet the amount of money and resources available for devoting to noise technology research could require research support from the Federal Government. In this context "industries" means the entire industry and not simply a single company.

Problems arising from system or component interactions. Involvement of the Federal Government is needed in such areas of interaction because individual industries cannot solve these problems alone. Many of the noises associated with surface transportation operations are not the result of any one industry's products but instead the result of interactions from products of different industries. Tire roadway interaction is an example. The study of noise emissions resulting from this interaction requires expertise in not only tire mechanisms but in pavement materials and surfaces as well.

Maintenance of in-house capability. The Federal Government needs to have a capability to assess, to some degree on its own, the status and developments with respect to noise control technology; and as such should have, at least on a small scale, an in-house capability to undertake some parts of the RD&D chain. In this regard the Federal Government should never put itself into a position where one-hundred percent of its research work is contracted out.

2.b. For what products and industries should the Federal Government be undertaking noise research?

The Federal Government should conduct applied research and demonstration programs as needed to fill gaps left by industrial activity in order to meet societal needs and in particular, basic (high-risk) research.

Transfer of research into marketable technology leading to a commercial product is the province of industry and the Federal Government should not be involved.

The Federal Government should support necessary demonstration programs that must be done in partnership with industry. A program in the surface transportation area such as the DOT "Quiet Truck" program is an example of this type of government and industry cooperation.

2.c. What other areas of noise generation should receive Federal research support?

The Federal Government should develop an integral national noise study including all noise sources to determine current noise levels (without resorting to unjustified extrapolation) and determine the changes anticipated in national noise levels due to voluntary or mandatory noise reductions. These determinations should be updated periodically.

The Federal Government should play a leading role in research to develop the necessary measurement methodologies. For measurement methodologies that impact private industry, the Federal Government should work with industry to develop domestic and international measurement procedures.

Highway design variables, such as land-use planning, zoning, noise barriers, etc., should be further investigated by the Federal Government as possible methods of noise-control technology.

Government research on new materials should continue through demonstration and development of products if there are no private manufacturers in business making the materials.

Federal transportation grants should permit in-service test of new concepts prior to spending on capital equipment for putting such concepts into production.

2.d. What future technology developments will influence noise control and/or research?

Future developments include the following:

Dieselization and weight reduction of motor vehicles

Improved communication can lead to less of a need for personal travel, thus less noise impact from vehicles

Use of electric and other alternative propulsion technologies

Noise impact of new tire designs intended to increase fuel efficiency

Future developments with respect to repaving of parts of the nation's highways may affect tire noise

Overall surface transportation system changes in response to fuel economy and emission control requirements may affect vehicle noise.

2.e. What are the principal factors that need to be shown in demonstration programs to encourage adoption by industry?

If adoption and utilization of developed technology is to be encouraged through demonstration programs, these programs must show through in-service testing such factors as: practicability, durability, maintainability, reliability, functional performance, and initial and operating costs.

3. What role should the private sector play in developing noise control technology?

3.a. Can industry solve the noise problems without input from and assistance of the Federal Government?

The major responsibility for the development of needed technology rests with private industry. Once the Federal Government identifies a need to reduce product noise through regulation and sets a required sound level to be met by a class of products, then private industry alone should be involved in product sound-level reduction.

A minority view with respect to Federal involvement once a product regulation is set is that the Government should not be excluded from supporting basic research on the product for the following reasons:

Industry's results are too closely guarded and real information may be too slow in coming to the surface.

Industry's initiatives may be too weak, if research does not hold out future monetary gains.

3.b. What are the incentives for noise-control RD&D by equipment manufacturers and users?

Research incentives for the surface transportation industry result primarily from impending regulations. These incentives can be sharpened by better definition of national objectives. Under certain situations market competition can also serve as a strong incentive. An example of market incentives is the demand for passenger cars with low interior noise levels. Additional incentives include:

Profit (return on investment, payback period)

Good marketability

Financial and technical feasibility to manufacture the low noise product

Relatively low risk, i.e., results from research can be expected to pay off

Avoidance of regulatory actions through voluntary implementation of noise control measures

Meeting existing or future regulations

Improvement of corporate image

3.c. In what specific areas should noise-control research be done by private industry?

As stated in the response to subissue 3a, above, "private industry alone should be involved in product sound-level reduction [to meet a sound level required by the Government]." Transfer of research into marketable technology is the province of industry.

3.d. What are the constraints that inhibit development of noise-control technology by industry?

Some of the inhibiting factors are the direct opposites of the incentives listed in response to issue 3b. Additional inhibiting factors are:

Resource limitations to do research--marginal industries and companies have constraints on their abilities to participate in transferring research into a marketable product. A lack of facilities and trained personnel may also be a factor.

Test procedures that do not reflect actual product usage--a product may be quieter in use than the test indicates.

Competing societal needs and incompatible requirements--there are higher priorities than noise control, such as, safety, fuel economy, and exhaust emissions control.

Multiple regulations--international, Federal, State, and local governments may impose different requirements on the same product.

Regulatory uncertainty--when a manufacturer cannot plan for future years, development of a new or existing product line can be inhibited. As a consequence of uncertain regulatory actions, industry may cease to invest funds in a product because of the possibility that the product may never be allowed to be marketed.

Anti-trust restrictions restrict communication between companies--companies cannot discuss details such as implementation costs and product development plans. This restricted communication slows down the process of information transfer to some degree and inhibits the adoption of new ideas. Research efforts sometimes must be duplicated by other companies.

3.e. What role should educational institutions play in solving noise problems?

Universities should provide undergraduate introduction to and graduate programs in noise control. Educational institutions should also conduct basic research under both Government and industry auspices, with close oversight by the sponsors to provide incentives for best creative efforts. This also relates to Government-industry cooperation. High costs of instrumentation and facilities limit the ability of universities to conduct research.

The university sector should be involved when needs for test methodologies or levels are being defined. Universities can provide an independent source of data and validation.

4. How and in which areas can Government and industry work together on noise RD&D programs?

4.a. What methods or procedures can be utilized to disseminate and implement the results of successful RD&D programs?

Communication of research results can be satisfactorily achieved through the combined use of workshops, technical society meetings and journals, and formal contractor reports.

Implementation of results can be accelerated by Government procurement of "quiet products" on a wider basis, including State and local purchases.

4.b. What specific noise-control demonstration programs would aid equipment manufacturers and users to introduce noise-control measures?

The purpose of a noise demonstration program should be to provide a transfer of technology from the research stage to the state where products are introduced into commerce. Demonstration programs should be of sufficient scale to evaluate the durability, maintainability, reliability, and initial and operational cost characteristics of an advanced product in the real world. They should also be oriented to evaluate any possible accidental benefits in performance and other qualities. Demonstrations should include exposure to a full range of geographical and operational environments, and should be conducted with properly trained maintenance and operational personnel.

Noise demonstration programs should not be laboratory research type programs but programs that can be achieved on a production basis. This requires a sufficient definition of the demonstration program. If the demonstration program requires manufacturers' products, the respective manufacturers should be consulted to help in representative product selection.

Technology application demonstrations should be supported as joint cooperative efforts with industry (e.g., the Quiet-Truck program).

Industry can cooperate with Government through provision of services and equipment--Government should provide funds for engineering.

Government and industry should work together to demonstrate advanced exhaust system design. This would include vibration isolation between engine and exhaust components, new acoustical and structural materials, light-weight, low volume, low back-pressure and low shell-noise technology techniques.

An advanced cooling-system demonstration program is needed and should be based on a systems approach. The optimum trade-off between energy consumption, cost, and noise reduction should be established.

4.c. What forum or mechanism can be used effectively to provide for an exchange between Government and industry concerning noise research needs and accomplishments?

Open review by the private sector of the progress made on research programs sponsored by the Federal Government would serve as a means of fostering the interchange of technical information. The current meetings that EPA/ONAC holds to review the progress being made on the various EPA-sponsored studies with industry and universities on the internal combustion engine were cited as an example. The Federal Government should be invited to monitor the progress being made in the various industry trade association research projects.

A need exists for a single focal point within the Federal Government to which questions on research can be directed and from which answers can be obtained. EPA/ONAC was cited as the Federal Agency that should handle this. One of the responsibilities of this focal point should be to coordinate the dissemination of information on the research programs of all Federal Agencies. Periodic newsletters were cited as one of the mechanisms that could be utilized to keep information flowing to all interested parties.

Technical coordinating committees made up of representatives from the Federal Government and the private sector (industry, universities, etc.) should be formed to facilitate communications relating to noise technology and research. These committees should meet regularly and continuously. Activities of this body could include:

Technology assessments

Preview of on-going and planned Federal research programs

Participation in the planning of Federal research programs

One or more committees might be formed to focus on a specific area or areas as necessary, such as tire and road interaction noise. Such a committee would be made up of the various elements associated with tire noise technology and pavement design.

Cooperative work programs, in which industry and government people are exchanged for short periods of time, would foster communication and an exchange of ideas.

Professional society meetings and technical committees, such as SAE, were identified to be effective mechanisms for technical exchanges. The need for government participation in these activities was cited.

Symposia, such as this particular symposium, are an effective mechanism for obtaining broad perspectives on any given issue.

IIC. AVIATION WORKSHOP RESPONSES TO ISSUES

1. What Is the Status of Aviation Noise Control Technology?

It was a consensus view that at the current state of aircraft noise control technology, significant operating cost and performance penalties result from noise reduction to meet FAR 36 (stage 3) certification levels. The magnitudes of the penalties vary widely depending on whether the design is for an entirely new aircraft, for a stretched version of an existing aircraft, or for an engine retrofit without growth in payload or range. While much of the noise reduction in existing CTOL aircraft has resulted from design features which also improved aircraft performance and reduced operating costs, some features incorporated to meet the constraints of noise regulations result in reduced performance and increased operating costs. For current designs of new 3-engine aircraft there is about a 6 percent penalty payload to gross weight ratio due to design for noise certification levels 5 EPNdB below 1969 FAR 36, and there is a corresponding increase in fuel consumption of about 3 percent. Retrofit of higher bypass ratio engines to existing airframes is very expensive in direct operating cost unless the aircraft can be reconfigured to accommodate more payloads.

Significant penalties in performance and direct operating costs result from the necessity to design for noise levels about 3 EPNdB below certification levels to allow for uncertainties in the prediction of the noise levels which the developed aircraft will produce. The opportunity to reduce these uncertainties provides a strong incentive for noise R&D.

The acoustics of various engine noise sources is an extremely complex and difficult technology subject. With very substantial input of research effort by the government and the industry in the past 10 years, significant advances in basic understanding of the mechanisms of the various sources are beginning to be made. It is vital that the momentum of this progress be continued, if practical applications of some of the basic work toward reduced noise are to be realized and

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more broadly expanded. Currently, the methodology of acoustics prediction and noise control design for aircraft engines is by no means adequately developed. This lack of precision in the noise design art generally leads to poor trades between noise and performance. It is hoped that with accelerated effort, the noise design technology can be brought to a comparable level of maturity as those in other engine component design disciplines.

At the current state of noise control technology, reduction of noise levels appreciably below FAR 36 (stage 3) would result to very large penalties in payload/gross weight ratio and fuel burned, the penalty rising at an increasing rate as the noise limit is lowered. Extensive R&D on noise control is required to make levels below FAR 36 (stage 3) technologically feasible. New technology is needed not only for CTOL aircraft, including propeller-driven types, but for STOL aircraft and helicopters as well.

The workshop was structured to identify and roughly prioritize, within each technical area, the new technology needed for noise control. No attempt was made to establish priorities across the technical areas of engine noise, airframe noise, rotor and propeller noise, and propagation, nor to allocate resources. Specific recommendations are mainly technical in nature.

2. What Role Should the Federal Government Play in Developing Aviation Noise Control Technology?

- A large and expanding federal role is recommended.

  The total annual funding for Federal programs in aviation noise research now totals about \$25M (combined Fiscal Year funding and manpower) and is roughly comparable to funding for related programs by the aviation industry. Discussion indicated that the Federal support for aviation noise research should be approximately doubled in the near future and that this increased level of support be used to sponsor additional grants and contracts for basic and applied research

- A sustained federal program is necessary.

  In order to meet the long term EPA noise goal of $65L_{DN}$ in communities near airports a sustained program of basic research will be essential to provide a favorable climate for the generation of new ideas and innovations, whereas applied research activities will advance the required design and prediction methodology. Program continuity also provides for the specialized training of research personnel and the maintenance of research teams, both of which are vital to the effective advancement of noise control technology.

- particular federal agencies were foreseen to have specific roles as follows:

  DOD - Continuing of mission oriented research at a relatively low support level

  FAA - Rulemaking and serving as an alternate source for research funding

  EPA - Coordinating of the Federal program and defining overall strategy and goals

  NASA - Sustaining a major research and technology program to include those items requiring long duration efforts and/or high risks. The desirability of NASA participation in coordination of research in certain specific technical areas was indicated

It was noted that the Federal Government should accept the role as leader in the development of acceptable noise propagation prediction methods. Because such methodology would have general application outside the field of aircraft noise, the Government should also accept the responsibility for funding the bulk of this much needed effort. Discussion indicated that while there are substantial Government funded efforts currently in progress in several different Agencies to develop such prediction methods, they do not seem to be well coordinated. It is therefore recommended that a single Agency within the Government be assigned the leadership responsibility.

- Special advice to NASA:

  The NASA, which has the largest segment of the federal noise research program, was singled out for some particular advice. It was recommended that emphasis be continued by NASA on research and technology aspects and that demonstration activities be very carefully selected. Needs were cited for long range planning of NASA programs to be coordinated with industry to assure maximum relevancy and ultimate utilization of research results, improvements in the timely communication of NASA research results to industry, and more effective NASA-industry communications and collaborative activities. It was noted that needs exist for a large quiet wind tunnel for the testing of full-scale aircraft and components for aeroacoustic purposes. Modifications to the existing Ames 40x80 and 80x120 foot wind tunnels were mentioned as possibilities for meeting such needs in the landing approach and take off-climbout speed ranges.

3. What Role Should the Private Sector Play in Developing Aviation Noise Control Technology?

- Some industry noise control initiatives result from competitive pressures.

  Social pressures arising from adverse reactions to noise is forcing manufacturers of aircraft to produce quieter and more efficient flight vehicles than the competition. Such noise control initiatives arise from market place pressures caused by such diverse factors as airport curfews and differential landing fees, and litigation.

- Industry programs should complement government programs.

  Industry programs are now comparable in magnitude to those of the Federal Government. In order to complement the primary Federal Government role in the support of long duration and/or high risk basic and applied research, industry should continue to perform the short duration and/or low risk technology applications to specific configurations. Active participation in the validation of methodology, in the performance of trade-off studies, and in the development and proving of new technology (including research techniques) are appropriate roles for industry.

- Industry participation is essential in validation.

  Industry participation should also complement that of the Federal Government in the development and validation of prediction techniques such as those suitable for use in the NASA ANOP program. The procedures so developed are apt to be more useful to potential users in industry if industry has a part in the full scale flight evaluations and subsequent improvement exercises.

- Technology integration is a role of industry.

  Industry should conduct trade-off studies to show the relationships of noise control to cost and performance. It is only by trade-off studies performed within the normal constraints of industry that the true value of new technology can be established. An ultimate proof of new technology is its adoption by industry.

4. What Aviation Noise Research Areas Require Federal Support? What Programs in Progress Require Further Emphasis?

Engine noise remains the principal source of noise impact in the airport community from CTOL aircraft. Significant progress has been made in the past in reducing engine noise through the introduction of high bypass ratio turbofan engines to reduce jet noise, modification of fan design concepts and development of duct liner technology to suppress fan tones. Further noise reduction progress is difficult and will come slowly due to the present balance of noise from many sources within current engines. No longer can progress in noise reduction be made by reducing just jet noise and just fan noise. Rather, progress must come through research leading to the simultaneous reduction of noise from several engine sources.

Highest priority research areas. The highest priority research areas are concerned with the dominant sources on present engines. The dominant sources vary from application to application, and for takeoff and landing power, and depend strongly on bypass ratio (BPR).

1. Jet noise, both high- and low-bypass ratio. Jet noise remains the dominant source of noise on takeoff for both narrow and wide-body CTOL aircraft. Increasing bypass ratio has been the main approach to lowering jet noise, but is limited by the performance penalties that result at higher bypass ratios. Suppressors do not exist for efficiently controlling this noise for growth versions of existing aircraft or new aircraft. Research is needed to understand the mechanisms of noise generation, the propagation of noise through the exhaust, the understanding of forward velocity and installation effects, and the generation and development of noise suppression concepts. For example, the use of internal mixers for both jet noise reduction and propulsive efficiency improvement for high bypass ratio CTOL aircraft should receive research attention.

2. Fan noise generation and duct propagation. Fan noise is the dominant noise source on most current generation aircraft at approach power. Fan noise can impact the community either when propagated

forward through the inlet or rearward through the bypass duct. Research is needed that will improve the understanding of fan noise generation, propagation through and radiation from inlet and exhaust ducts, and development of ground test methods that simulate forward velocity effects on these problems. The development of a comprehensive prediction method that is consistent with fundamental aeroacoustic theory and accounting for all the important source mechanisms is most critically needed. Ground test procedures are also needed which limit the noise generation during static testing to those sources associated with flight. Fan noise technology is now to the point that low noise fan and duct design concepts should receive more emphasis.

3. Duct treatment. A duct treatment technology exists and is being applied to the control of fan tones in all current aircraft. However, design of this treatment is largely an art, requiring experience, cut and try methods, and extensive testing. Needed is a better understanding of the suppression mechanisms of the duct liners, the effects of flow on suppression, and design procedures which would enable the matching of the treatment to the true noise sources, or duct modal structure, in flight. New lining concepts should be explored.

4. High velocity jet noise. SST-type aircraft cannot utilize the high bypass ratio engines which have been so successful for subsonic aircraft since supersonic cruise requires a high velocity jet (very low bypass ratio). Before an SST is environmentally viable, we must be able to control the noise of high velocity jets or develop a new engine cycle that generates lower jet velocity on takeoff, such as the variable cycle engine. Research must include an understanding of shock cell and jet mixing noise, prediction of installation and forward velocity effects, and methods of suppression. Applied research effort to optimize the designs of many previously proposed and tested mechanical suppressor schemes to match the engine cycle or exhaust.

Lower priority research areas. Still important, but of lower priority than those listed above, are several additional sources for noise control. These are research areas which offer payoff in the future or where progress must be made before engine noise can be lowered significantly on advanced engines.

1. Advanced inlets. This general area is felt to have long-range potential for controlling forward radiated noise from engine nacelles. The concepts combine accelerating flows with treatment technology for more efficient suppression of forward radiated noise. Generally included are such concepts as sonic or hybrid inlets. Also included are geometric concepts such as the scooped or scalloped inlet. Such inlets offer the potential for major noise reductions in the future.

2. Core noise. Core noise is the noise generated within the engine core (other than turbine noise) which is propagated through the exhaust. It is currently observable for some turbofan engines and can become a dominant noise source on future turbofan engines when low frequency jet exahust noise has been reduced significantly, and on turboshaft engines. Its sources, such as in the combustion process or in the internal flow aerodynamics, must be understood and design procedures evolved for its prediction and control.

3. Turbine noise. High frequency turbine noise propagates out the exhaust and is an important source of noise on today's high bypass ratio CTOLs at approach power. Acoustical linings are used to reduce the turbine noise in today's engines. Future engine turbine designs having higher turbine aerodynamic loading and pressure ratios are expected to raise the relative importance of this source of noise. It is important that new research efforts toward better understanding of methods to reduce the noise at the sources be undertaken.

4. Test and instrumentation technology. Progress in engine noise reduction will be impeded without special test and instrumentation technology for diagnosis of noise sources and performance evaluation of noise control devices. Laser technology for sensing fluid dynamic and acoustic phenomena, data

processing and acquisition techniques for separating noise from multiple sources, low signal to noise ratio data processing techniques, turbulence control screens for static engine testing, and very quiet aeroacoustic test facilities are in this category.

Research scope. The principal areas of research needs are in the fundamental and applied areas. The consensus is that long-term payoffs can only come from such an emphasis. Across the board, in all the engine noise areas, there is a need for understanding and prediction of flight effects. This includes methods for ground test that result in data that can be reliably extrapolated to flight conditions. In all cases, research needs to be aimed at understanding noise generation, predictive schemes, and the creation of a design methodology from which suppression concepts can evolve.

Facility needs. Some sentiment was expressed for a large-scale, quiet wind tunnel facility to meet national needs. The need can probably be met by acoustical treatment of the 40x80 tunnel at Ames Research Center. It should be capable of handling the wide body class of high bypass ratio engines and should have a background noise level sufficiently low to permit the study of core noise, turbine noise, etc., on future, quieter engines. The tunnel would be used for both research and development, and possibly for certification of engines prior to flight.

Payoff. The guaranteed results of an expansion of research in these areas would be a maturing of the process of designing for noise. A more mature design technology could be translated into either lower noise levels or equivalent noise levels with fewer cost/performance penalties, and in lower dollar cost for developing quieter new aircraft. However, major noise reduction can only come through new concepts or breakthroughs, which cannot be guaranteed. Therefore, an expansion of the research program can only offer increased opportunities for breakthroughs. Certainly, new concepts and breakthroughs will not result unless the various problems under discussion are actively subjects for research. In terms of actual noise reduction, the group felt that 5-10 EPNdB in 10-20 years, relative to present high bypass ratio turbofan noise is possible. The spread in noise reduction and time is a function of the magnitude and aggressiveness with which the research program is conducted.

Requirements. The scope and difficulty of the research needs for engine noise reduction lead to the conclusion that present funding levels are insufficient. More than token progress can only be made by significant increases. The group felt that a reasonable starting point would be to increase the Federal funding level for noise R&D by a factor of two starting in FY 81.

- Airframe noise research requirements involve both nonpropulsive and propulsive flow interaction sources.

  Non-propulsive Flow Sources. Involved are airflows not associated with the aircraft propulsion system and which flow over the airframe and interact with various components such as flaps, landing gear, wheel wells, etc., to produce noise. The primary need is for accurate validated prediction schemes which can be used to assess the importance of the airframe noise problem from a firm base. Reliable flight data, uncontaminated by engine noise, are needed for the validation. The identification of noise sources needs to be pursued more vigorously. New and unexpected sources, such as flap brackets and edges, have recently been identified. Noise control/reduction cannot proceed in a rational manner until the sources are known. The development of scaling rules must be pursued in order to determine the applicability of model scale tests to the full scale problem. A large scale quiet flow facility is needed for a vigorous ground based research program on airframe noise. Emphasis should now be placed on improving the fundamental understanding of the generation and prediction of the noise, with research on identification and development of noise reduction concepts receiving lower priority.

  Propulsive Flow Sources. Involved are airflows from the exhausts of jet engines and the slipstreams of propellers which flow over portions of the wing and produce noise. Such flow surface interaction noise problems are expected on all STOL vehicles having integrated lift-propulsion systems and are of concern for interior noise as well as exterior noise. Existing flyover noise prediction methods are based on small scale model testing and it is thus desirable to acquire flight test data on the QSRA and the two AMST aircraft for validation purposes.

Impingement/flow surface interactions which affect flyover noise are also expected on CTOL vehicles. On CTOL aircraft these problems include possible prop wake/wing interactions on aircraft such as the C-130 and the proposed high speed turboprop airplanes. Moreover, some proposed SST configurations employ over-the-wing engine locations which involve jet exhaust associated impingements on the wings. These latter CTOL related phenomena should be given a higher research priority than related phenomena which are unique to STOL configurations.

- Rotorcraft related noise research requirements involve both the external and internal environments, and include refinements in the understanding of rotor and gear box noise generation and prediction, and the full scale validation of prediction methods.

Validation and Refinement of Gearbox Noise Prediction. Currently, first level interior noise prediction methods exist for an uninstalled transmission/gearbox. Such methods require detailed structural modeling and dynamic response characteristics. Refinements are required to improve the accuracy of high-frequency component amplification and resonances and to account for installed effects. Since helicopter gearbox designs are configuration dominated, validation of these methods is necessary for a variety of designs and installations. Although the noise transmission paths from the gearbox to the interior of the vehicle are different for turboprop CTOLs than for the helicopter, the fundamental generation and prediction technology are similar.

Refinement and Validation of Overall Rotor Noise Prediction. Rotor noise prediction methods require refinements and full scale validation to improve accuracies sufficient for design purposes. Pending certification requirements will specify compliance levels for three flight conditions: flyover, approach, and takeoff. While some tradeoff or allowances in levels will be permitted between these three conditions, accuracies on the order of at least

2 to 3 EPNdB are necessary. Once certification is promulgated, helicopters must be designed below the compliance limits by the accuracy margins in order to assure a high probability of certification.

Establishment of a Data Base. Validation of rotor prediction methods requires systematic noise data acquisition for a variety of rotor types and main/tail rotor combinations. This data base must include simultaneous measurements of the vehicle noise characteristics and the rotor aerodynamics (including fluctuations). Additionally, the data base must be broad enough to adequately account for airspeed, rate of descent, rate of climb, gross weight and control variations.

Development of Main Rotor Broadband Noise Prediction Method. Rotor tip speed reduction and increases in number of blades result in a higher relative contribution of broadband noise. First level prediction methods tend to underpredict the broadband component, particularly for modern rotor types with advanced airfoils, twist distributions, and tip shapes. Improved prediction methods are required now which take into account these design variables.

Evaluation of Installation Effects on Tail Rotor Noise. The noise of tail rotors exceeds that of main rotors in some configurations and can be directly influenced by main rotor downwash, the proximity of the tailboom, the engine exhaust flow, and in forward flight, by disturbed flow past the fuselage. The influence of each significant effect on noise generation must be isolated and quantified. This entails whirl stand and wind tunnel testing of both unshrouded and shrouded tail rotor configurations followed by free-flight.

- Propeller related noise research requirements involve both external and internal environments and include research relating to G/A, Large Conventional Propeller and Proposed High Speed Turboprop (HST) Aircraft.

Development and Validation of Cabin Noise Prediction Procedures Applicable to G/A, Large Conventional Propeller and HST Aircraft. The mechanisms of noise transmission into a propeller aircraft are not well understood. Transmission paths for noise have not been confirmed by test although work on a single engine G/A aircraft is now underway to establish the magnitude of engine vibration and noise structurally transmitted to the cabin. This work on single engine aircraft should be expanded to include multi-engine G/A aircraft and large multi-engine propeller aircraft.

Work is also underway on theoretical methodology for predicting the noise transmission characteristics of fuselage sidewalls in G/A aircraft. Validation of this methodology is also underway on a limited basis. Engineering-type computer programs should be developed from the theoretical methodology after validity has been established. Validation of this work by industry should be expanded and trade-off studies which include industry should be conducted to establish cabin interior noise control concepts. This work should also be expanded to consider larger conventional propeller aircraft including the new aircraft required for the expanding commuter market.

The cabin noise of the HST must be consistent with that of current turbofan aircraft for it to have the passenger acceptability needed to be a viable fuel efficient alternative to current large transport aircraft. The program underway to develop validated procedures for predicting the near field noise of the HST should be continued for use in noise reduction studies and also to provide the input to fuselage noise transmission prediction procedures. Studies of noise transmission of fuselage walls and the HST are underway. However, the validity of the methodology used in these studies has not been fully established. Development of new methodology which addresses the high cruise speed and transonic tip speed operation of the HST is required.

A data base for validation work is needed and should be obtained with the participation of industry.

Continue Existing Program to Optimize the Aeroacoustic Performance of G/A Propellers and Expand the Effort to include Innovative Propulsor Designs. The existing NASA and EPA programs to develop and validate prediction procedures for G/A propellers is endorsed. The close cooperation with industry in this work should continue to insure the early introduction of new noise reduction concepts on production aircraft. This work should be expanded to evaluate the potential of innovative noise reduction concepts such as the Q-Fan, a shrouded propulsor.

Experimentally Evaluate and Develop Validated Procedures to Predict Installation Effects on G/A, Large Propeller, and HST Aircraft. The effects of installing a propeller on an aircraft should be established by measurements on existing aircraft. The effects of nacelle tilt, the blockage of the nacelle behind the propeller and the presence of the wing and fuselage near the propeller are all areas of needed investigation. Validated procedures should then be developed to predict the noise of installation effects identified as important in the experimental program. This work is considered particularly important for development of new large turboprop aircraft using conventional propeller technology. Installation effects on these aircraft have been identified as a problem in meeting the FAR 36 (stage 3) noise requirements.

Develop and Validate Methods for Predicting Reverse Thrust Noise of Propeller Aircraft. The possibility of regulating reverse thrust noise has been discussed in international meetings. If reverse thrust noise is indeed a community noise problem, a validated prediction method is required. At present, very little is known about this noise component. Some definitive measurements of existing installations should be made and then a prediction method should be developed which can be validated by the test data.

Develop and Validate Methods for Predicting Noise of Turboshaft Engines. Core noise of turbofan engines has not been considered a significant problem and has therefore received much less attention than fan and jet noise which are the dominant noise control problems in current turbofan transports and the supersonic transport. However, in a turboshaft engine, the core noise is dominant and will require attention in G/A, large conventional and HST aircraft. Valid prediction procedures suited for existing and advanced technology engines are required.

Develop and Validate a Method for Predicting Airport Noise and High Speed Cruise Noise of the HST. During takeoff and landing, the HST operates at tip speeds similar to existing turboprop aircraft, and this is believed to result in acceptable noise levels around the airport. During high speed cruise at high altitude, the HST will operate at transonic tip speeds. Validation methodology is needed to predict the airport noise and the noise on the ground under the flight path.

- Aviation noise propagation research needs involve basic studies of air attenuation, extra ground attenuation, path interruption and sound transmission through structures; and the development of improved noise exposure prediction methods.

Large Distance Air and Ground Attentuation. The top priority need in propagation research is the development and validation of methods to predict attenuation over large distances including both air and ground effects. Although fundamental air absorption in a constant, controlled environment is considered to be fairly well understood, there is a need for additional data at frequencies below 4,000 Hz. In addition, substantial work is needed to develop prediction methods which define propagation losses through a non-homogeneous and/or turbulent atmosphere over the large distances significant for land use planning (typical of the outdoor propagation situation), and for a range of weather conditions. The significance of non-linear effects for aviation noise propagation also needs to be established.

Prediction methods for extra ground attenuation are not validated and no well accepted standards exist. There are existing theories for this general phenomenon based on idealized acoustical impedance models of the ground, but they have not yet been validated to any significant degree. The several existing prediction methods are empirical in nature. They are generally based on an inadequate data base and provide widely varying results. Standardized methods of measuring ground impedance are also required.

Path Interruption. Path interruption includes such items as shielding of the source by airframe/engine configurations, or attenuation near a receiver by barriers, other ground structures, or ground cover, such as vegetation. Theories exist for predicting airframe/engine shielding effects and these have been partly validated by research at the Institute of Sound and Vibration, United Kingdom. Theoretical models also exist for predicting effectiveness of most practical barrier designs but further research is needed to validate the effectiveness of thick barriers such as earth berms and buildings. Furthermore, existing barrier design models have not been validated for application to shielding of distant receivers near airport boundaries. There are also theoretical models which account for excess attenuation effects attributable to ground topography and various types of ground cover or vegetation, but their applicability to noise abatement near airports is limited.

Transmission Through Building Structures. With the exception of mobile home structures, practical models exist or will soon be available (from HUD) for the prediction of noise transmission through, and effectiveness of sound (and thermal) insulation of buildings. Limited data are available to validate the noise reduction effectiveness of such treatments. However, a much broader sample of basic noise reduction performance of existing structures for aircraft noise, as distinguished from other sources, is needed. In addition, validation data for predicted effectiveness of noise reduction treatment of buildings is relatively limited.

Methods of Measuring Atmospheric Properties. Standardized methods of measuring the atmospheric properties such as temperature, humidity, wind, ambient pressure, etc., are required in order to properly represent the atmosphere through which sound may travel over its propagation path, from air to ground or ground to ground.

Further Development and Validation of Airport Noise Prediction Model. Local public officials, airport operators, and land use planners need a usable validated model for noise impact prediction at and around airports. These people currently are faced with numerous models, data gaps, and confusion among Federal agencies on predictive validity. An accurate procedure for calculating aircraft noise exposure is needed with a good data base on noise for all commercial aircraft, noise for general aviation aircraft, noise information on operational procedures; and a method for adjusting for random or deliberate variation in flight tracks.

The model should be validated to account for meteorological conditions as well as source and procedural data with as narrow a confidence span as possible. This is an urgent need. Land use decisions around airports are being made every day, usually without considering noise. The multiplicity of models and questions about validity are barriers to effective involvement of local public officials in land use planning around airports. A generally acceptable prediction method of proven validity is needed as a tool in protecting undeveloped land around existing airports.

5. Are Demonstration Programs Needed to Stimulate the Adoption of Advanced Aviation Noise Technology?

- Carefully selected demonstrations will be needed. The role of selected demonstrations is to encourage the application of new technology in production aircraft while keeping the risk to industry at a minimum. A prerequisite for any demonstration is a package of new technology, well understood and previously validated at laboratory scale, together with the design constraints encountered in a real world situation.

- Specific items requiring demonstrations are identified. Needs are anticipated for full scale demonstrations of selected propulsion system components for helicopters, G/A aircraft, high speed turboprop aircraft and CTOL aircraft requiring mechanical jet noise suppressors as follows:

Jet Noise Mechanical Suppressors. For high specific thrust (high exhaust jet velocity) engine systems such as possible future design AST engines, the ability to substantially reduce the jet exhaust noise is critical in meeting environmental requirements. A large number of mechanical suppressor design concepts have been successfully demonstrated in scale model form in the past, and the reasons for their effectiveness are well understood theoretically. A limited number of such boilerplate designs have also been successfully demonstrated in engine sizes either in actual flight or in wind tunnel environments. The next step needed is a suitable demonstrator program to test in flight or in simulated flight specific designs that reflect a greater degree of realism in terms of acceptable mechanical design complexity, weight and performance impacts. Consideration should also be given to the demonstration of a fully retractable design, in order to assess its mechanical acceptability.

Non-Propulsive Noise Sources. Ultimately, some full scale wind tunnel and flight testing is necessary if airframe noise reduction methods are to have credibility; however, the manufacturers would prefer to have Government research funding spent primarily on fundamentals at this time.

Helicopter Rotors. Advanced configurations designed to check particular theoretical concepts or prediction schemes, or which represent optimized aeroacoustic designs, require flight demonstration. Existing single-rotor and tandem-rotor helicopters provide a means to test a variety of configurations. The Army/NASA Rotor Systems Research Aircraft also provides a testbed for large single-rotor designs which can be tested over an extensive range of gross weights and airspeeds.

General Aviation Propulsion Systems. The demonstration of noise reduction by new propeller configurations is planned and should be continued. This is believed to be a low cost and low risk program which does not require extensive Federal Government support. On the other hand, a possible flight demonstration of the Q-Fan, a recently tested wind tunnel low pressure ratio shrouded propulsor, is an example of an innovative high cost and high risk program which probably would require extensive Government support.

High Speed Turboprop. It is not now possible to acceptably test the high powered multibladed propellers proposed for high Mach number CTOL applications. Thus, short of full scale flight tests, a number of questions relating to the seriousness of the cruise far field noise problem and the cabin interior noise problem will remain. Demonstration flight tests are required at realistic flight conditions and for realistic fuselage structures.

III. KEYNOTE ADDRESSES

Mr. Charles L. Elkins
Deputy Assistant Administrator
for Noise Control Programs
U.S. Environmental Protection Agency

I'm very pleased to be here this morning to welcome all of you to EPA's Noise Technology Research Symposium. We hope this Symposium will serve as a major milestone in the development of a National Noise Control Research Program. I'm sure that all of us fully recognize that if we are to reduce noise created by the products of our society, we need to have available an adequate technology base and that research is the key to the development of that base.

I'd like to take a few minutes to tell you why we decided to hold this Symposium and what we hope can be accomplished during the next three days. In 1976 in pursuing our congressional directive to coordinate the noise research of the Federal Government we formed three Federal interagency panels to address the technology research areas of aviation, surface transportation and machinery and construction equipment. Mr. Harry Johnson, then Director of the Aeronautical Propulsion Division of NASA was Chairman of the Aviation Panel and Mr. Joseph Lamonica, Chief of the Division of Health for Mine Safety and Health Administration, was Chairman of the Machinery and Construction Panel and Mr. Harry Close who was then Director of the Office of Noise Abatement of the Department of Transportation was Chairman of the Surface Transportation Panel. Each of these panels reviewed all of the major Noise Technology Research Programs underway in the Federal Government from fiscal year 1975 through 1978. These panels also collectively assessed from their perspectives the adequacy and the direction of the total Federal Noise Technology Research Program. Each of these panels published a report and the EPA then published an overview summary report and you have all been given copies of these reports.

These reports were provided to Congress in April of 1978 to support the oversight hearings on the Noise Control Act of 1972 which were ongoing at that time. And as a result of those hearings Congress passed and the President signed in November the Quiet Communities Act of 1978. This act provides new directives to EPA to conduct and promote the advancement of noise control technology through research, and these directives emphasize the important role of other Federal Agencies in the achievement of this objective.

This Symposium represents our initial response to these Congressional directives. By bringing together this group we are asking you to help us launch a more aggressive, more sharply focused noise technology research effort in which all segments of society can participate for the benefit of all of us. We have convened this three-day Symposium to fully review noise control technology needs, incorporating the perspectives of all interested parties, not just those of the involved Federal Agencies. We hope that the report of this Symposium will provide a national research agenda which will help the Federal government set its research priorities and which can serve as a guide for research by the private sector as well.

To bring the broadest possible perspectives into play in reviewing the national noise research needs, we've asked a diverse group of participants and experts to participate in this Symposium. We have as participants representatives from Federal Agencies and Departments, State and local governments, industrial manufacturers and users, trade associations, unions, public interest groups, universities and international interests. We've asked representatives from the Senate Committee on Environment and Public Works and the White House Office of Science and Technology Policy to be keynote speakers to provide you with the thoughts and concerns of the executive and legislative branches of the Federal government in relation to the national policy of noise abatement and control. And we have also asked a representative from the Economic Commission for Europe to speak to us so that we may obtain some perspectives on European technology research and development.

Let me briefly summarize some of EPA's own perspectives on this problem. Excessive noise created by aircraft, various surface transportation modes and industrial plants and equipment is degrading the quality of life for many people in America. Much can be done by the incorporation of available technology but studies we have done show that this will not be sufficient.

In the aviation area we have, as we all know, a situation in which airport operators are facing millions of dollars of lawsuits. In our view these lawsuits so far represent only the tip of the iceberg. The recent promulgation of more stringent levels for new production aircraft will help but the trend to larger aircraft and the forecasted increase in operations will wipe out the benefits of these regulations for those who live around airports as we go into the Twenty-First Century. Unless, that is, further action is taken.

Turning to urban traffic noise, this is a serious noise problem for some ninety-seven million Americans. Trucks, buses, motorcycles, light vehicles and rail carriers are all sources of this excessive transportation noise. Increases in the numbers of these sources will, in time, wipe out the noise reduction benefits which have already been promised in the Federal regulations. Technological changes brought on by the requirements for improved energy efficiency may intensify the noise problems.

In the occupational noise area some three-and-a-half to four million industrial workers have occupational noise exposures which exceed OSHA's requirements. As you know, the principal consequence and concern with excessive work place noise is the permanent loss of hearing the workers can incur. Faced with OSHA's requirements to reduce noise in the work place through engineering controls, industry has apparently been unable in some cases to do so because of the absence of technically feasible methods. And it is no news to most of you that serious hearing loss is taking place among workers even in those plants which meet the OSHA standards. Further reduction is needed in these plants as well, in our view, and technology will probably be a constraint in some of these cases also. In all of these areas hearing loss and other auditory effects of noise such as sleep and speech interference are not the only concern. There has been increasing scientific evidence that noise may also be a contributing factor in various physical and psychological diseases. Although these research studies do not fall within the purview of this meeting and its objectives, the Quiet Communities Act does direct EPA to support research on these non-auditory effects of noise, and we plan to do so beginning in October of this year.

As a final word on EPA's perspective, it is our view that support for industrial technology research and technology innovation and development is essential for the survival and growth of our economy. The U.S. economy is suffering a slowdown in productivity with a growth rate that is now slower than that of most other major industrial nations.

Technology research necessary to support the environmental demands of our society should, whenever possible, be coordinated with these research programs relating to productivity development. We know foreign governments are doing a great deal to support their civilian research and development programs and so too we would like to work with the private sector or develop in concert a National Noise Technology Research Program.

The Quiet Communities Act of 1978 enhances EPA's role in the noise research area. EPA is encouraged to conduct or to finance research on the control of noise with either public or private organizations. This includes development and demonstration of noise control technology. We at EPA would like to use the results of this workshop to help support and give additional focus to the Noise Technology Research Programs of each of the Federal Agencies and Departments involved in noise research, including now EPA. We also hope that individual companies will find the results of this Symposium helpful in establishing new research priorities.

Three days is a very short time in which to accomplish this objective. To be most productive during our meeting, may I suggest that we agree to do the following: first, direct our attention to noise technology research needs. Discussions of noise effects research needs or instrumentation and measurement needs should be postponed until a later time. Secondly, avoid philosophical discussions related to regulatory concerns; specifically, the need or the lack of need for regulations or current regulatory actions. I'm sure there are strong opinions here about the Federal government's regulatory program but these discussions will divert us from our objectives here. We welcome these comments at other times and places, however. Thirdly, keep the objectives in mind and remember that we have a limited time in which to address some very difficult issues. So let's maximize our efforts to develop conclusions and recommendations. Fourthly, make sure your views are heard. Because of the nature of the Symposium we have tried to maximize the output by restricting the total number of participants. So in some cases many of you are the only representatives of a particular interest. We need each of you to take an active role in these discussions because if you don't express your views they may not be incorporated in the conclusions of this Symposium and in the shaping of a national noise control technology research Agenda for the future.

I want to thank each of you for your support. I want to assure you that we at EPA are going to work very hard to obtain the support of the Congress, the President and the private sector, support which will be necessary to meet the national noise technology research needs ahead. We hope you will do these things as well. Let's begin by producing a well thought out report of the deliberations of this Symposium. We look forward to working with you during the next three days to produce this report. Thank you.

Mr. Carl Gerber
Executive Office of the President
Office of Science and Technology Policy

I am pleased to be here this morning and to deliver one of the keynote addresses to this important symposium for which EPA has gathered a cross section of people involved and interested in noise technology research. Noise is something that affects everyone of us in our daily lives and is an issue in many countries as well. Chuck discussed the magnitude of the noise problem and the need for noise research with you.

I would like to address the subject of this symposium in the context of overall Federal research and development policy. The Office of Science and Technology Policy which I am representing here today is concerned that all Federal decisions, not just regulatory, are made on the basis of sound scientific and technical information to the maximum extent feasible. To achieve this goal we encourage and endorse efforts to develop needed scientific and technical information. We recognize that resources are limited and are particularly supportive of efforts such as this symposium that can identify the most critical needs. Equally important is the involvement of all sections of our society in developing the scientific and technical information base, for it is clear that the Federal government cannot--and indeed need not--be the sole generator of information. Much knowledge and capability exist in the private sector that can and must be tapped.

However, even in a period of budget austerity, the Federal government remains committed to and supportive of development of the needed technical information. Dr. Press, the Director of the Office of Science and Technology Policy and Science Advisor to the President, and President Carter himself are both firmly committed to a sound, Federally supported basic research and development program. President Carter in his 1980 fiscal budget message to Congress said, and I quote:

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> "I believe that the Federal government must lead the way in investing in the Nation's future. Despite necessary overall constraints, this budget continues my policy of providing real growth in Federal support of basic research. Such support is a relatively small fraction of the total budget--$4.6 billion in 1980--but is vital to the future of our Nation. The knowledge created through basic research holds the potential for breakthroughs to the solution of problems we face or will face in such critical areas as agriculture, health, environment, energy, defense, and the overall productivity of our economy. Higher productivity gains in the future, moreover, will make an important contribution to reducing inflation."

While support for research and development remains a major Federal goal, the total burden and responsibility for research and development funding must be shared by the private sector. The basic Federal philosophy involves funding those research areas where the pay-off may be distant and those development projects where the initial costs and risk might prohibit private investment. When such projects reach a development or demonstration stage where industry investment is feasible and attractive, it is our feeling that Federal support should be phased out and the private sector take over.

This approach has evolved from the basic belief that industry is somewhat reluctant to engage in major exploratory basic research because of the length of time it takes for the payback, sometimes twenty-five years. In addition, basic research is difficult to keep secret and as a result some sectors of industry see little financial incentive in investing in basic research. On the other hand, it is more likely that the private sector will engage in a high-technology applied research area where the return on the investment is more secure.

The extent of industrial investment involved in research and development is currently under study as part of a presidentially directed interagency study on industrial innovation. This study, a Domestic Policy Review led by the Department of Commerce and involving some thirty Federal Agencies and offices, is now well under way. More than one hundred persons from business and industry are serving on specific task forces set up by the Department of Commerce and the Department of the Treasury. It is proceeding on the premise that innovation is a complex process influenced by a great number of factors, many but not all of which are affected by government policies and programs. The study is covering a number of issue or option areas. These include: economic and trade policy; environmental, health and safety regulations; tax policies and venture capital formulation; Federal procurement practices; direct Federal support of research and development; patents and information; the regulation of industry structure and competition; and managerial philosophy and practices affecting research and development.

The goal of this study, as in the case of all Domestic Policy Reviews, is to present the President with a series of highly focused options. The study will attempt also to indicate the impact of these options on specific sectors. The President's economic advisors and inflation fighters are extremely interested in the innovation study for they recognize that longer term gains against inflation must derive from improved productivity, new economic growth, and improved international competitiveness of American products.

Of course there are no guarantees that all the proposals made will be universally adopted. In a matter as complex and far-reaching as this there are bound to be differing ideas and some disagreement as to the possible solutions. However, this study represents the highest level of attention this issue has ever received in the government, and the study group is working closely with industry, academia, labor, and public interest groups to get the fullest and broadest input possible.

Without trying to predict or preempt the outcome of this study, I would like to discuss briefly the bearing research has on innovation. There is, however, considerable difference of opinion of the role that research plays in the total process of innovation. Some people feel that it is a mistake to identify innovation too closely with research. This view stems from the idea that the initial invention or discovery is only a small part of the innovation, which depends more for its success on development and marketing. This view, I believe, is too narrow and shortsighted, particularly for innovations in high-technology fields. Such innovations will increasingly have to come from new discoveries in basic science and engineering, from research that will allow us to develop strikingly new products and processes rather than depend solely on incremental improvements.

We cannot expect to transcend our environmental problems, improve our efficiency in using energy and materials, and move into new, high-technology frontiers without considerable advances in basic research. While incremental innovations are important, we can expect most of our competition from abroad to come in the class of incremental innovation.

If we are going to show real leadership we must operate from a strong base of new knowledge. And we must find better ways to apply that knowledge to new processes, products and services that can in turn spawn broader economic growth.

It is worthwhile also, I believe, to raise a point or two on industrial based research and development, particularly as it relates to the Federal role. One attitude voiced by some industry officials is that private industry seeks the removal of disincentives to research and development much more than direct Federal funding of industrial research and development. There appears to be a widespread feeling that regulations, tax structures and other government activities inhibit innovative research and force companies to concentrate on defensive research, incremental product change and marketing.

Let me focus for a moment on this. Regulation in particular is cited today as a major inhibiting force against innovation. The argument is that compliance is generally very costly and draws off company talent and resources that could be devoted to new developments. There are some problems in this area and, as a result, there is already some government effort underway to prune regulations, simplify requirements and reporting and coordinate the actions of the regulatory agencies. The President has established a regulatory council, presently headed by EPA Administrator Costle, to examine for the first time all of the proposed regulatory actions of the Executive Departments, non-independent agencies and when they agree the actions of the independent regulatory agencies as well.

This council will not only prepare a calendar listing all regulatory activities underway but will undertake some crosscutting studies such as impact on specific industries or specific groups in our society. Also the council may become involved in the planning of research activities to support regulatory activities.

While arguments against current regulations may be valid to some degree, government regulatory actions must be viewed in perspective with other goals of our society. We must strike some balance in this matter. Thus, though we cannot afford a mindless pursuit of a totally pristine environment, we dare not follow the other extreme of abandoning reasonable goals and efforts in order to give ourselves a quick shot of economic growth, however attractive that might appear at the moment.

Our approach to solving these complex problems must be rational. Among other things, our approach should seek to gain a better understanding of the present regulatory process and how to improve such processes. In particular we need to focus more on the adequacy of data, their interpretation and means of systems-wide risk/benefit analysis. We need to come to grips with the dilemma posed by the evergrowing capability to measure ever smaller quantities and the question of very low level effects. Industrial and academic research can help us gain more certainty about biological effects and technological solutions and thus help government agencies base their regulations on more definitive knowledge. This should help bring about a greater confidence in Federal decision-making and broader consensus on regulation. But even with better information we will still face making decisions based on considerable uncertainty and there will continue to be disagreement on the best course of action.

In addition to discussing Federal support of research and development and examining industrial research and innovation, it also is useful to mention, at least briefly, the university-industry relationship.

There is no doubt that American academia and industry have had distinct differences and virtues related to research. Our university research thrived and won world renown because of its environment of freedom and independence. That environment has allowed for the fullest bloom of scientific inquiry. It has attracted the best minds from within this country and abroad. It has permitted development of a most productive relationship between education and research, between student and professor. As a result it has generated an enormous fund of scientific knowledge and continues to do so.

On the other hand, American industry has also benefited from the ability to operate in a free market, to choose its own mode of operations and its own approach to the pursuit of profits. Though on these bases it would seem that both institutions operate in two different worlds with entirely different motivations, there are strong connections between them.

Industry has relied on the broad fund of research results universities provide. The universities are the source of its new scientists, engineers and technicians. But even while its virtues have been recognized, through the years there has been a feeling that more could be done to make this relationship more productive.

A number of differences have traditionally divided industry and academia. A few of these have been persistent and are still basic to some of the problems we face in this area. Perhaps the most persistent from industry's view springs from the fundamental differences mentioned earlier. Industry generally feels that most universities are not empathetic to the needs of industry and this reflects in the training of graduate scientists and engineers. Indications of this were confirmed several years ago when a survey of the presidents of some seven hundred and fifty major companies revealed that more than half were less than satisfied with the doctoral scientists and engineers they had hired. Other follow-up studies have corroborated this finding.

Of course, from the university researchers' standpoint we hear the other side of this issue: the complaints that industrial research is too product-and-market oriented, that its planning is too short-term, that it is hesitant about taking risks. This is not the atmosphere in which university people are trained so there is bound to be a somewhat strained relationship.

It is unlikely, due to the basic nature of the two institutions, that we are going to resolve these problems completely. And perhaps we should not for there are some fundamental virtues in the different roles these institutions play and it might weaken both if they became too much alike. We should not want our university research system to become exclusively an applied research arm of industry any more than we want our industrial companies to lose their drive that comes from market orientation. However, whether industry believes it or not, much of industry's future lies in the results of the untargeted basic research taking place in the universities, research that is publicly supported mainly by government funding.

On the other hand, the university researcher should not overlook the fact that to a considerable extent industry's short-term gains are what generates the funds that support basic research. In spite of their different roles there is a symbiotic relationship and it is one that should continue.

Much has and is being done by industry and the universities themselves to improve their relationship in research and development but, in addition, the government has undertaken several efforts to bring these two groups closer together.

One Federal agency that pioneered this activity was the Department of Defense's Advance Research Project Agency, ARPA. In the mid-1960's ARPA undertook a specific goal-oriented materials research program that established university-industry teams to work in defined fields. This was an experimental program aimed at the coupling of university and industry. ARPA also has conducted a cooperative program in computer sciences that has been instrumental in advancing certain aspects of the computer industry.

Another agency that has been active in encouraging university-industry interaction is the National Science Foundation. The NSF has approached this through such mechanisms as supporting university-industry workshops, organized research areas and research initiation grants.

Though not the focus of this symposium, the development of a better understanding of the risks posed by noise is an underlying need that must be addressed. Unfortunately, it is not now possible and may never be to determine the precise effects and degree of risk posed by exposure to noise. So in noise, as with all other potentially hazardous activities and substances, control decisions must be made on a conservative basis.

Most environmental agents which affect health are foreign to man's evolutionary experience; noise, however, differs in being an excess of what is, at lower levels, a necessary, beneficial and natural process. Therefore, for noise exposure the crucial issues are related to quantifying the deleterious effects which occur in the transition range between exposures to sounds which are necessary and beneficial and exposures which are clearly harmful. This was examined in detail in 1976-77 by a task force on environmental health under the direction of the National Institute of Environmental Health Sciences, NIEHS.

The health effects of noise exposure can be divided into those that are direct and those that are indirect. Direct effects include both temporary and permanent loss of hearing as well as non-aural physiologic effects. Hearing loss is related to exposure level, to the recovery period between exposures and to the number and duration of exposures. Indirect effects, as Chuck mentioned, include those related to communication, to performance and other behavioral patterns and to annoyance.

The NIEHS task force found considerable progress has been made in quantifying the noise environment existing in the United States since publication of an earlier task force report in 1970. This information was accrued in large part from activities generated by the Occupational Safety and Health Act and the Noise Control Act of 1972.

For additional discussion of the health effects and related research needs I refer you to the report of the second task force for research planning entitled "Human Health and the Environment: Some Research Needs." It was published by HEW in 1977.

Given the long time it will take to develop a better understanding of the effects of noise on humans, it is crucial that resources in both the public and private sectors be devoted to examining what technological changes can be made to reduce noise. And it is important in this quest to examine, in addition to incremental technological changes, what major, new innovations are needed not only to reduce noise but also to achieve other socially desirable goals such as energy efficiency and increased productivity. Without an adequate understanding of the effect of noise on humans and the technological means of controlling it, decisions will be made that might either create a hazard to human health or impose an unnecessary economic burden on society.

Equally important to identifying national research and development needs is deciding how we as a nation, both the public and private sectors, can meet these research and development needs. Critical to both identifying R&D needs and determining the priorities in which these needs are addressed is the active participation in this process by all sectors: government, industry, academia, labor and the public. These are formidable tasks and I wish you success as you undertake them.

Dr. George Jacobson
U.S. Senate Staff
Environment and Public Works Committee

I am very pleased to be here today, and I look forward to this symposium as a good educational experience. I don't have the technical expertise in noise technology or acoustical engineering that most of you have, but because of our subcommittee responsibilities for control of noise pollution, I have become very committed to doing whatever is possible to reduce the levels of environmental noise in this country.

I should say at the outset that I will be speaking primarily for myself. It's fair to say that no one person speaks for Congress, although some of you may think the problem is that there is a surplus of volunteers.

I will resist making jokes about noise pollution in Washington.

Seriously, I consider it a great honor to have been associated with Senator John Culver and the Committee on Environment and Public Works. I have especially enjoyed the opportunity to work on issues related to the control and reduction of environmental noise.

Congress has been involved for about nine years now in noise control and related legislation. Several of the previous speakers have mentioned some of those laws. I'll run through them again and make some observations about what Congress had intended. During the next few minutes my attempt will be to discuss current congressional interests and concerns in this area.

After considering the issue for several years, Congress finally passed the Noise Control Act in 1972. That law did two important things. There were several sub-issues as well, but the major impact of that law was to give EPA the responsibility to identify major sources of noise in this country, and then to establish regulations which set the upper limit on noise that could be emitted by certain products at the time of their manufacture. In that 1972 law was also a charter for EPA research in the area of noise control. This included research on health effects and on control technology. In addition, and probably more importantly, there was a charter to EPA to coordinate the entire Federal research effort in this area.

For various reasons Congress didn't pay too much attention to what happened in the noise program for several years. There were other major pieces of environmental legislation emerging from the Public Works Committee during that time. As you know, the Clean Air Act, the Federal Water Pollution Control Act, and several other major anti-pollution laws now on the books came out of this committee. It's no surprise that those issues took up the attention of those responsible for the noise matters.

Then about two years ago the General Accounting Office, an investigative arm of Congress, began a review of EPA's noise program. That resulted in a report that was somewhat critical, justly perhaps, of the slowness with which EPA was implementing the 1972 Act--namely identifying noise sources and then promulgating regulations. At about the same time came the creation of the Subcommittee on Resource Protection, under the chairmanship of Senator Culver. The subcommittee was given jurisdiction over noise control, so we immediately began looking into the broad issue of noise control legislation and the noise program in EPA.

Last year we conducted extensive oversight hearings on the 1972 Act, at the same time soliciting suggestions of ways in which there could be greater advances made.

Witnesses included representatives of several Federal Agencies involved--EPA and the Department of Transportation. We heard from State and local officials who were running noise control programs, from scientific experts in the area of noise control technology and in the area of health effects research, and we heard as well from several experts in noise law.

As a result of those hearings Senator Culver introduced the Quiet Communities Act which eventually did pass Congress and was signed by the President last November (PL 95-609). The new Act included a reauthorization of the 1972 act, so in that sense it didn't reduce EPA's authority. But it also amended the original noise law by redirecting EPA in several important areas. First, to provide technical assistance and support to State and local programs around the country and, second, to support research in the areas of control technology and health effects.

I might just take a moment to explain the reasoning behind our move to shift EPA's efforts more toward providing support for State and local noise control programs. In our review during the last several years it became apparent that the regulations EPA had promulgated should have a positive effect some years in the future, when a new generation of trucks, garbage compactors, motorcycles, or whatever come into use. There ought to be a noticeable reduction in the noise produced by individual machines.

But, on the other hand, if only the Federal regulations are in effect and there is no follow-up, those benefits will certainly be lost--overcome by the fact that the number of new machines in operation is increasing so rapidly that the total volume of noise will remain as high or higher than the 1970 level. Furthermore, there must be a concerted effort to insure maintenance and monitoring of these machines wherever they're used. It's clear that EPA itself cannot enforce the law and monitor the machinery in every city of this country.

At the same time we determined that since 1970 an increasing number of communities around the country were becoming interested in developing their own noise control programs. Those programs may include very simple monitoring of community noise, or ordinances restricting the output of noise from a given piece of property, or even temporal or spatial zoning so that certain kinds of noise are restricted to certain parts of the city.

However, local officials were very direct in stating that their prime concern was a lack of expertise on their part. They simply did not have the trained personnel or the equipment--even simple equipment--necessary to conduct their programs in an effective way.

So the Quiet Communities Act was seen as the impetus to help EPA provide the technical assistance, training, and perhaps even the equipment, to communities and States around the country, so that there could be a coordinated and complementary effort by Federal, State and local governments. The idea then becomes to regulate at the Federal level those few items for which that would be effective, but then to deal with local problems separately as they occur. Each community tends to have its own special situation because of the local geography, the way the community has been laid out, and existing State and local laws.

The research goals for fiscal year 1979 were described in the Quiet Communities Act, but each year our subcommittee also passes a separate piece of legislation authorizing the budget for EPA's entire research and development effort. In that Act last year we included four million dollars for noise-related research. This was split with two million dollars for research on noise control technology, and two million dollars to study primarily non-auditory health effects of excessive noise. Unfortunately, the Senate and House Appropriations Committee didn't support that particular segment of our authorization bill. However, the President's budget proposal for fiscal year 1980 does contain half a million dollars for noise-related research.

I think it's fair to say that EPA's role in actually conducting this research will remain small, and therefore its efforts to coordinate research conducted by other Federal Agencies, universities, and industry will probably be most important.

Now I'd like to say a few words about how I perceive future congressional interest and what we would hope to see happen. Congress reacts similarly to industry in some ways, in wanting to see research be productive in a real sense--not just producing research papers, but rather results that will show up on the marketplace. Congressional opinion about the Federally supported research in noise control is much the same. It's not enough that the research is going on, but that research should be having some beneficial effects. The results should not be just quieter machinery, but ultimately a quieter environment.

When Congress passes laws like the Noise Control Act or the Quiet Communities Act it's with the intention of improving the quality of the environment and improving the health and welfare of our citizens. Any Federal research should be productive in the sense that it's helping industry and helping the nation have quieter machines. At the same time, we are looking at Federal regulations to see that they are not simply in place on the books, but that they are, in fact, having an effect in reducing environmental noise. To be frank I must say that it's not clear that any of these things is happening at this point.

It is perhaps too soon to expect to see the effect of regulations on new machinery, because most of the trucks, buses and motorcycles on the road are older generation vehicles. But presumably within the next decade, depending on the generation time for these machines, we should be able to see some positive effects.

As a general philosophy in developing all its environmental legislation, the Committee on Environment and Public Works has taken a strong and consistent position that regulations set either by Congress or by the Environmental Protection Agency be strong enough to "drive" research in a particular field. In other words, standards should be tough enough so that at least for future years they can not be satisfied by current technologies. Therefore it becomes imperative for anyone involved with those industries to be active at the forefront of research and making real progress.

Apparently, this has worked quite well in the control of air and water pollution. I think it's clear that scrubbers were developed quickly because of the clean air standards. Despite the fact that scrubbers are not a particularly elegant solution, and we hope they will not be the final solution in cleaning up stack emissions, they nevertheless work better than anything else available today and they've had a positive effect on air quality.

There is a real question whether EPA's regulations in the noise area have, in fact, driven industry to advance the frontiers of research. There may have been a limited positive effect, but this is something I'm kind of anxious to learn about at this meeting. But as I said, if there is any criticism that would come from our committee, it would be that the standards were not stringent enough to force real advances in control technology.

I would say that our committee, and I think the same would be true for the House Committee with this jurisdiction, is quite willing at some point to try new approaches to control noise pollution. We're not wedded to the idea of having regulations like those now on the books. Perhaps some type of national ambient standard, or possibly the concept of noise charges should be explored more carefully. These are the sorts of things that we will be looking at during coming years if it appears that the present approach is not effective in reducing environmental noise.

It is a little beyond the scope of this meeting, but we are also very interested in knowing what are the real costs of noise to society. Anytime we talk about regulations or legislation it is important to know the real costs to the nation of a given pollutant. In this case it's clear that there are large economic costs to the nation from noise pollution, although there aren't yet many well-documented studies. Property values alone must have been affected by billions of dollars across the country. And at the same time the incremental costs of health care are probably larger than many of us would suspect. But, again, these particular areas have not been well-studied, and should be part of a broader research effort stimulated by the Federal government.

Our committee feels strongly that we need more effective cooperation between a number of different groups in carrying out noise-related research. This is especially true of Federal Agencies themselves. In the history of noise control over the last seven or eight years those Agencies have, for the most part, not been extremely successful in cooperating in a productive way. I hope this is changing now. It certainly is something we're trying to encourage. That's difficult to do from the outside, but it's clear that if the FAA, EPA, and NASA are all working in different directions then that is not productive.

There is also a real need for cooperation between different levels of government--Federal, State and local--not only in the kinds of programs we are hoping to promote through EPA, but also in the general sharing of information and support from other Federal Agencies. This is going on to some extent through the Department of Transportation, and I commend that, but there certainly can be much more that is done.

And finally, as Carl Gerber said very nicely, there has to be a better relationship than there has been in the past between the government and universities and industry. This is something that can be enormously successful if it is carried off. That may be one way by which the productivity of our nation's research institutions can be most quickly uplifted.

I will summarize by saying that I have guarded optimism about the prospects of reducing environmental noise in our country. I am strongly committed to it personally, and I will do everything I can, working through our committee, to see that this happens. Certainly I welcome any suggestions any of you have. I hope to talk with as many of you personally in the next three days as is possible. Chuck Elkins was correct in saying that this meeting should not dwell on regulations and legislation, but I would like to hear from you individually about them. Thank you.

Dr. Claude Lamure
Director
Institut De Recherche Des Transports
Centre D'Evaluation Et De Recherche Des Nuisances, France

The main noise problem in Europe has long been the noise of industrial machinery; for some fifteen years, however, the road traffic noise has kept increasing; it has affected almost the whole population whereas plane movements only disturb a comparatively smaller amount of people than in the U.S. Besides, recently built aircraft emit much lower noise levels than those we had in the past decades even though they carry far more passengers; this accounts for the fact that many researchers in Europe are concerned with noise from ground transportation. On the other hand, let us mention that the acoustic insulation of blocks of flats has also been the topic of active research, for the greater half of European families live in flats. Yet, we shall only deal here with the problems of terrestrial transport noise.

This address was accompanied by photographic slides which are omitted in the present text.

I. PROTECTION AGAINST THE NOISE OF HEAVY TRAFFIC ROADS

I_1 - MEASURING AND ESTIMATING THE TRAFFIC NOISE HAS BROUGHT FORTH QUITE A NUMBER OF STUDIES IN THE UNIVERSITIES, PUBLIC RESEARCH ESTABLISHMENTS AND ALSO A FEW PRIVATE COMPANIES.

First, governments had to decide on units to measure the fluctuating noise emitted by road or railway traffic. In the past few years, most European countries have adopted Leq in dB(A) to evaluate day nuisances. Great Britain alone which was -by far- the first country to act in this field has kept the L_{10}. As regards sleep disturbance, active European studies sponsored by the EEC should enable to decide on a complementary noise index for the night within 2 years. Let us also mention that some research works are specially devoted to the nuisance and propagation of low frequencies emitted by the vehicles (TRRL in G.B. - IRT Cern in France). The accepted limits of Leq during the day in front of the facades of houses is 65dB(A) in France.

Numerous methods have been then elaborated to predict the traffic noise.

I_2 - METHODS FOR PREDICTING TRAFFIC NOISE LEVELS IN EUROPE

Methods for predicting traffic noise levels have been or are being developed in different countries of Europe, with the following characteristics.

- Most of them are Leq-based methods (Denmark, France, Germany, Netherlands...) The others are L_{10} methods, but tend to be adapted to estimate Leq (Switzerland, U.K.).
- Most of them are regarded at a national level as operational methods for protection, evaluation or

planning purpose, by reference to the national noise criteria or guide lines involved, (for example:

$Leq_{24\ hours}$ 45 dBA satisfying

Danish guidelines)

$Leq_{24\ hours}$ 55 dBA unsatisfying

- These methods include simple nomograms or formulas, computer-based methods, and scale model methods. Some methods include several steps (2 steps in Denmark, 4 steps in France...), with increasing complexity, precision, and cost.
- Some of the methods can be applied to railway noise or/an industry noise prediction as well as road noise (Netherlands, Switzerland...).

The computer models for traffic noise prediction which exist within the European countries are different concerning structure of algorithm, acoustic laws implied, input parameters and output results, cost and precision, type of application.

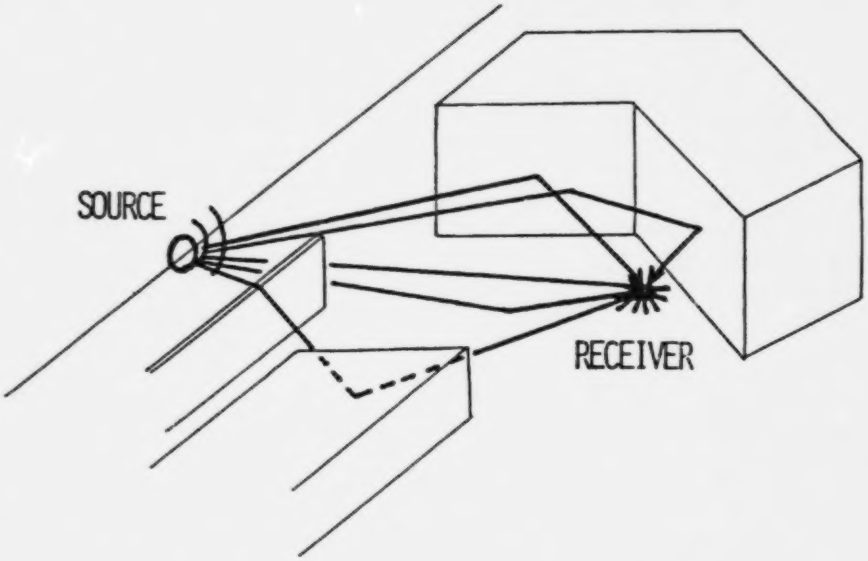
I_3 - PREDICTION OF MOTORWAY NOISE LEVELS IN FRANCE - COMPUTER MODEL

The following methods have been described in the Noise Guide ("Guide du Bruit des Transports Terrestres - Ministere de l'Equipement - 1976-1978 Paris"), they are of current use by road engineers and planners in France. The first is a simplified method: five successive charts or nomograms, which use the following input data: traffic volume, speed, distance to the road, percentage of heavy vehicles, gradient and angle of view - give a single value of Leq. This value is a rough prediction, which makes the users determine whether or not there is a noise problem at the location considered.

The second is a detailed, nomograph-based method, where a good knowledge of traffic and site configuration is assumed - the calculation is done step by step, and includes detailed site configuration parameters (ground effect, reflective facades, diffracting edges). This method estimates Leq levels accurately in most situations. It can be used for the estimation of noise barrier protection effect. But the method can be time-consuming with rising site complexity.

The third method (3) involves the same parameters as the previous one, by use of the computer program BRUIT. This program has been developed to process complex built-up area situations, where the nomogram-based method supposes a lot of calculations. In this program, distance, air and ground attenuation, multiple reflection and diffraction by obstacles are assumed, on the basis of an algorithm which searches for the acoustic paths between any two points of the space, one source and one receiver (figure 1).

FIGURE 1



COMPUTER MODEL "BRUIT".

EXAMPLES OF ACOUSTIC PATHS TO BE COMPUTED

The data can be entered from a map of the site with an automatic reading table. A writing table draws a map and positions the Leq Levels.

The fourth method is the use of performant scale models for areas involving propagation paths of increasing complexity. Such facilities have been developed in France where they have been used for urban acoustic planning purpose, study of special acoustic devices such as road-covers or half covers and road noise propagation research.

The propagation is simulated with a model from a point source to a point receiver (the scale used is 1/100 at the C.S.T.B. Laboratory). A computer processes the source and microphone positions and the measured noise levels in order to compute Leq for the given traffic data.

These four methods from a very simple to a very sophisticated are very different in structure, cost, precision, handling, accuracy. Therefore the user has a good panel for choosing the best fit for his predictions and protection problem.

I_4 - PROTECTION MEANS ALONG THE ROADS

Building either walls or earth banks is now very common along the highways in the vicinity of metropolitan areas, such protection cut 10dB or more, they are more efficient for medium- or high-pitched frequencies as well as peak noises.

The technical problems are well known to civil engineers; the use of absorbents is still rather rare as the available materials are not entirely satisfactory and multiple-reflexion areas - which require such absorbents - are not that many. Generally, the shape of the barrier is designed in order to avoid harmful reflexions.

Since blocks of flats in Europe are generally high and close to roadways, it may be necessary to build very tall barriers such as the one bordering the Orly-Paris motorway - it is 9 meters high. Some barriers are made of glass, one type is both a noise and safety barrier. Mentioned below are a few examples of motorway noise control:

PROTECTION OF SINGLE-STORY HOUSES - After widening the previous 2 x 2 road to a 4 x 2 urbanmotorway the single-story houses turned out to be at 5-10 m from the curb-side, which can be considered as the "ideal" situation from a road noise control point of view, when a not too-high nor too-long acoustic barrier can be highly effective.

In this particular site, a 5 m high massive concrete barrier was erected at the curb after arrangement with residents (who preferred the barrier to double windows). This barrier is 140 m long, its efficiency is 10-14 dBA for the first row of houses. The cost was $700 (1975) per linear metre.

PROTECTION OF MEDIUM-SIZED BUILDINGS - In this area, the previous boulevard was in 1973 converted into a high-speed 2 x 3 road. As a result, the existing buildings were exposed to rapidly increasing noise levels, most of them exceeding 70 dBA (Leq).

This site includes (1) 4-story existing buildings, with 400 apartments; before protection, 50 of them were exposed to Leq levels from 73 to 76 dBA, (2) 10 hectares open area, where public service buildings have been planned (schools, hospital, etc.). Before protection, this area had 65-75 dBA Leq levels.

It was decided to to build a joint concrete barrier/earth berm, under the condition that the barrier would stop at the local street junction. After erection, the 5-6 m height/400 m long system has lowered the upper Leq levels down to 65-70 dBA (efficiency 4 to 11 dBA) for the buildings. The levels in the surrounding open field area have decreased to a maximum 65 dBA Leq level, which can be considered as acceptable. The total cost was $150,000 (1975), land price excluded.

PROTECTION OF SEVERAL TALL BUILDINGS NEAR A MOTORWAY BY A COVER - KREMLIN-BICETRE - In many situations (tall buildings), noise protection by screens would require unrealistic heights. One has then either to reinforce the noise protection of the facades, or to cover the road. This very costly solution can be acoustically effective, but there are many problems to solve relative to geometry and acoustic characteristics of the system, stability, safety, and ventilation, etc. For the inner side must be carefully examined. The B6 motorway passes through Kremlin Bicetre in a depressed cut section between rows of 7-story old buildings. Leq levels before protection ranged from 75 up to 80 dBA. It was decided to close the section with a horizontal cover made of double iron plates. A ventilating noise-proofed system evacuates the exhaust gas. The 460 m cover was erected without stopping traffic. Its efficiency is about 15 dBA (the cover has a limited length; the reverberant field inside the cut section has increased; the local streets outside make noise etc.). The price of the cover was $500/m^2 (1978) including material, works, and light.

PROTECTION OF SEVERAL TALL BUILDINGS BY A HALF-COVER --GENNEVILLIERS - With the new A86 motorway near Paris, the noise control problem has been tackled at the study stage, and therefore the noise barriers integrated to the road as a whole. At Gennevilliers, this motorway passes along tall buildings, and a noise barrier would have been uneffective. Finally a half-cover has been set up on the building side of the motorway. This half-cover partially increases the reverberant field, but acts as a vertical barrier with a diffracting edge. It is not necessary to light the road because of translucid plastic panels, nor to ventilate. The price of the half-cover was of the same order as the previous one \$500/m^2, everything included.

I_5 - BUILDING INSULATION

In most cases, when dealing with built up areas or long-existing roads, it is necessary to insulate the facades of the buildings while maintaining a proper ventilation. Acoustic insulation techniques have improved significantly. Moreover the energy crisis has encouraged many people to use double glazing so that several systems are now available and very efficient both in acoustic and thermic matters.

Double glazing is not generally efficient against noise because the panes are too thin or too close. In this respect consumers are not well informed. However some systems using thick glass can be efficient.

PROTECTION OF A TALL BUILDING NEAR A MOTORWAY - A 5-story building is located at 15-30 m from the edge of the embanked motorway. In situ measurements show 72-74 dBA Leq levels; 76-78 dBA levels are expected in 1980. The noise insulation of the facade was about 20 dBA. Given the respective building and road position, building a noise barrier would have been unrealistic. In such a situation the last solution was to improve the sound proofing of the facade. It was done by doubling the windows with 8 mm glass and 46 mm thick wool, set up on balconies. The noise insulation thus obtained is about 30 dBA, for the outdoor window alone. The cost was \$1500 (1976) by dwelling. The technological progress to be hoped in facade insulation is highly dependent on the building practice and not on fundamental research.

II. REDUCING VEHICLE NOISE

Reducing noise at its source is presumably the best solution as it does not set any prerequisites to urban architecture and people's way of life. Besides it is the only way to reduce low frequencies.

Let us first recall what European regulations are as defined by the E.E.C.

II_1. REGULATIONS

A decree of 13 April 1972 states that the noise from motor vehicles must not exceed the levels given in the following table, the quoted values being subject to a tolerance of 1 dB.

These noise levels are measured in well-defined conditions. The microphone is located at a height of 7.5 m above the ground and at a distance of 7.5 m from the centre line of motion of the vehicle. The vehicle should be running in 2nd or 3rd gear depending on whether it is fitted with a 4 or more than 4 speed gear box and the engine should be running at 3/4 of the speed corresponding to maximum power output except where this would result in a vehicle speed or more than 50 km/h. Running under these conditions the vehicle should be accelerated at the maximum rate from a point 10 m before reaching the location directly opposite the microphone to a point 10 m beyond this same location. The noise level to be noted for the test should be the maximum value recorded during the traverse of the vehicle. These measuring conditions are the subject of the ISO R 362 standard.

The extent to which these maximum acceptable levels of noise are to be reduced in the future in terms of EEC regulations has already been decided.

	Type of vehicle	Maximum acceptable noise level (dBA)	
		Today	in '82
A.	Vehicles listed in section II of the Highway Code		
A1.	Private cars	82	80
A2.	Vehicles other than private cars having an all-up weight of 3.5 tons	84	81
A3.	Vehicles having an all-up weight greater than 3.5 tons and not included in category 4 or 5	89	82
A4.	Public transport vehicles having engines rated at 220 HP or more Autobus	91	85
	Autocars	91	87
A5.	Commercial vehicles having an all-up weight of 12 tons or more and an engine rated at 200 HP or more	91	88
C1.	Two-wheeled vehicles		
	C.1.1. Mopeds	73	
	C.1.2. Lightweight motorcycles	80	
	C.1.3. Motorcycles	84	
C2.	Vehicles having more than two wheels		
	C.2.1 Mopeds	74	
	C.2.2 Vehicles classed as lightweight motorcycles	81	

These new regulations are to come into force on 1 April 1980 for new models (except for public transport vehicles fitted with engines rated at 200 HP or more for which there is to be a 2 year delay) and 1 October 1982 for existing designs of vehicle. With these new regulations the maximum acceptable noise levels will be reduced by 2 dBA for private cars, by 3 dBA for the complete range of heavy vehicles and by 6 to 7 dBA for public transport vehicles.

The above arrangements apply in the case of approval tests on new vehicles and they involve the use of a suitable site and test equipment. It would however be difficult to check the condition of vehicles already in use in the same way. A decree of 14 April 1975 accordingly defines a test to be made at a fixed location that is applicable both in the case of approval tests on new vehicles and also for checking the condition of the exhaust systems of vehicles already in operation. The maximum acceptable levels quoted for new vehicles are increased by 5 dBA in the case of tests on vehicles already in operation.

It must be possible to reproduce the results without any difficulty when conducting approval tests to verify that new vehicles meet the requirements and when checking the condition of vehicles that are already in use. Fines can be applied when vehicles contravene the regulations (Article 62 of the Highway Code).

II_2. TECHNICAL RESEARCH ON REDUCING MECHANICAL NOISE

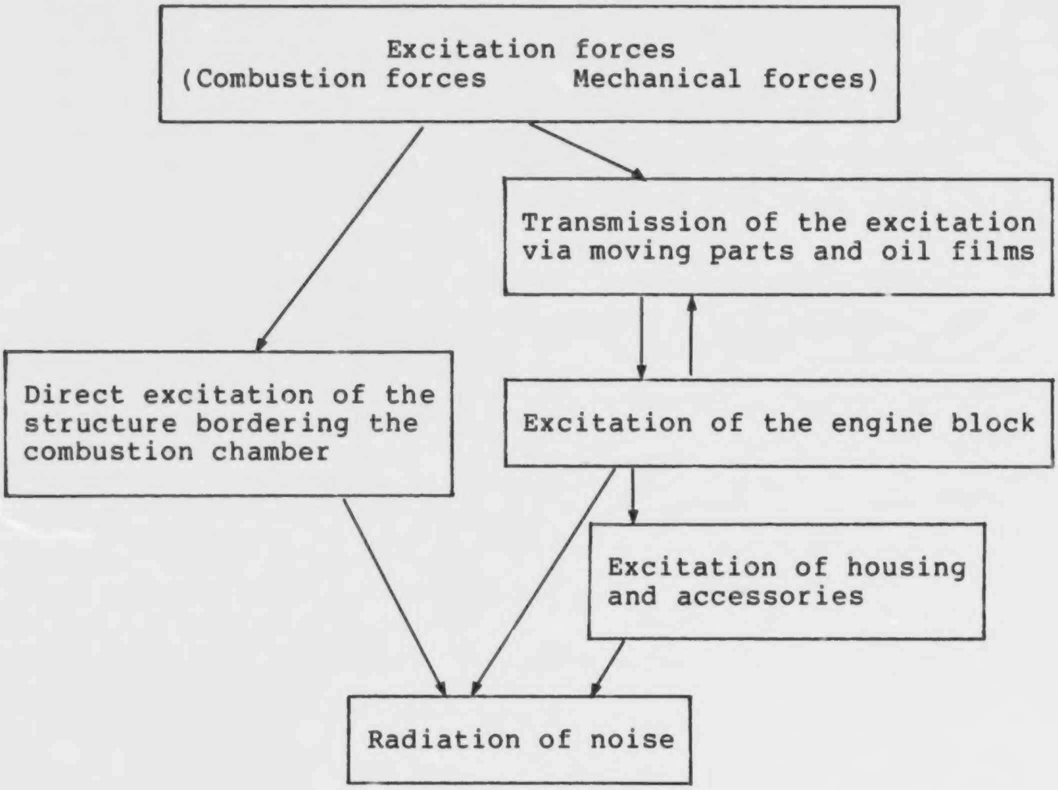
Although there are technical possibilities for reducing noise of mechanical origin there does not seem to be any prospect for the moment, or for some time to come, of reducing rolling noise (a symposium will be held on the topic of tire noise in Stockholm August 1979).

On the other hand an appreciable reduction in the overall noise level can only be achieved on dealing with all the important sources of noise since no one of them is really preponderant.

Research is generally carried out by the vehicle builders - as regards engines - though such public research establishments - as the ISVR in Southampton, the Anstalt fur Verbrennungsmotoren in Graz, Austria or the IFP in Paris have contributed a great deal to it. Governments often sponsor the part of the research they consider useful; in Great Britain the ISVR has launched a study on a quiet truck prototype, now resumed by Fodden and Rolls Royce.

II$_3$. ENGINE NOISE

The behavior of an engine with respect to the generation of noise and vibration can be represented to a first order of approximation by the following diagram:


Excitation forces
(Combustion forces Mechanical forces)
Transmission of the excitation via moving parts and oil films
Direct excitation of the structure bordering the combustion chamber
Excitation of the engine block
Excitation of housing and accessories
Radiation of noise

Thus the reduction of noise as a result of taking action on the engine itself can be concerned with the exciting force (explosion or combustion and the associated mechanical forces such as those due to side slap of the piston), with the transmission of that force via the moving parts and oil films or with the mechanical and acoustical response of the radiating structures involved (engine block, housing and accessories).

$\text{II}_{3.1}$. ACTION CONCERNING THE EXCITING FORCE

The mass of gas vibrating under the pressure resulting from the combustion excites the combustion chamber and the combustion noise is radiated from the cylinder head. At the same time the pressure exerted on the piston is transmitted to the moving parts attached to that piston and this gives rise to mechanical noise. Thus the cylinder pressure diagram is an important characteristic here since it is this characteristic which determines the amplitude and the frequency spectrum of the exciting force. This diagram is very different according to whether we are concerned with a spark ignition or a diesel engine and the parameters involved in any action that is taken will also be different. (I.F.P. Paris)

In the case of diesel engines the frequency spectrum of the exciting force can vary considerably given the wide variation in the design of the combustion chambers. Important parameters here are the rate of injection and the self-ignition delay and because of this it is found that natural intake direct injection engines, supercharged direct injection engines or engines with M type combustion chambers all behave differently with regard to the generation of noise and they do not respond in the same way to alterations to the same parameters. The noise emitted by a supercharged diesel engine is less than that emitted by a natural intake engine of the same power when both engines are running at a steady speed. This difference can however disappear when the speeds are changing with significant loads on the engines.

There are fewer factors contributing to differences in the case of spark ignition engines and in general for operation around the optimum power output point the important parameters to be controlled are the engine speed, the rate of charging of the cylinders and the compression ratio. Adjustment of these parameters can lead to a 1 to 3 dBA reduction in the noise emitted by the engine but this is at the expense of changes in the specific fuel consumption, increased pollution and the generation of smoke such that a compromise has to be made. (I.F.P. report to I.R.T.)

$\text{II}_{3.2}$. ACTION CONCERNING THE MOVING PARTS

It is now understood that useful results can be obtained by considering the transmission of the exciting forces and acting on the moving parts involved (connecting rods, crank arms, crank shafts). In particular we know that there can be undesirable effects when the resonant frequency excitation of the crank shaft can in turn excite resonant displacements of the engine block itself. If this can occur it may be necessary to consider new arrangements of the moving parts along the line of the crankshaft including the bearings but the results of doing this have not so far been very encouraging (Renault).

It is also know that the oil films play an essential role in the transmission of forces to the engine block. (I.S.V.R.)

A number of characteristic parameters have been studied on using a previously constructed experimental rig that enabled us to analyse the transmission of forces across an oil film. It was found that the oil film played an essential role in this transmission and that the behavior could be modelled (spring + damping system). It was shown that the transmission of forces was reduced on increasing the stress in the shaft or its play in the bearings or on reducing the speed of rotation of the shaft, its diameter (for the same amount of play), the width of the bearing block or the viscosity of the oil.

$II_3.3.$ ACTION CONCERNING THE DESIGN OF THE ENGINE BLOCK

There has been appreciable progress in this field in developing analytical procedures, in improving our knowledge of mechanical behavior of the structure and in making proposals for particular lines of research. Some of the work here is being carried out in specialist laboratories with an international reputation such as the Institute of Noise and Vibration at Southampton (U.K.).

The work that has been carried out was concerned first of all with the development of better procedures for investigating the acoustic and vibratory response of the engine block. Investigations concerning the deformation show that each engine block needs to be regarded as a particular case. It was shown that coupling between the crankshaft and the engine block was possible. The crankshaft amplifies the excitation frequencies that are close to its resonant frequencies. Thus it is necessary to examine ways of stiffening the engine block so that the resonant frequencies of this unit are a long way from those of the crankshaft.

- It is already known that the noise emitted by the engine block can be appreciably reduced (2-5 dBA) on treating certain accessory units coupled to the block where such units would otherwise normally be responsible for the radiation of a lot of noise. This reduction in noise can be achieved either on fitting appropriate jointing material or on enclosing the radiation elements. A closely fitting screen, i.e., a screen consisting, for example, of sheet metal lined with fibre glass that is directly attached to an integral part of the engine block can be quite effective in the case of a small and strongly radiating element. Such treatment is however difficult to apply if the element is of a complex shape and it is then better to consider modifications to the structural arrangement of the element itself.

Such treatment can yield good results but it can only be applied where relatively sophisticated experimental facilities are available and on the basis of a detailed analysis of the behavior of each type of engine.

- Modifications to the actual structure of the engine block can be made. The mass of the engine block can be increased which is useful as regards the reduction of noise but this is contrary to the present trend which is to reduce the weight of the block. A better approach is to obtain the required shift in resonant frequencies by appropriate stiffening of the structure or by making use of alloys or of composite materials in order to modify the mechanical response. Hopefully this will lead to appreciable reductions in noise (of the order of 5 dBA) in the long term.

- However in the near future, the combustion having been optimised and the accessories treated, use will be made of sound proofing hoods. Various applications have demonstrated both the effectiveness of this technique in reducing noise (5-8 dBA) and the technical and economic difficulties that can arise. Thus there are difficulties with regard to available space and the location of the hood and of access to the engine, difficulties with regard to cooling of the enclosed engine in that larger and more costly cooling systems are required which can themselves be noisier if this possibility does not receive due attention, difficulties with regard to reliability, fire risks and maintenance and finally there is the difficulty of finding suitable materials in that the effectiveness of the technique depends on the provision of absorbent materials which at the present time are not very suited to the application. Thus the use of hoods to reduce noise will require a new approach to the design as a whole such that the noise reducing facility is an integral part of the engine instead of being introduced into an engine compartment which was not designed from the start to accommodate the additional equipment. It should be noted that the difficulties that arise in fitting these hoods will vary considerably from one vehicle to another, certain vehicles (e.g., rear-engined buses) being already suited to their use.

- Noise could also be reduced on altering the cubic capacity and the speed of the engines. In fact noise increases with engine capacity and to a much greater extent with engine speed. In general, however, large capacity engines running at lower speeds emit less noise for the same power output than do smaller capacity engines. A decrease of 20 percent in engine speed for the same power output results in a reduction of about 2 dBA in the engine noise.

However, given the present situation with regard to the costs of motor vehicles and fuel this reduction of noise as a result of increasing engine capacity does not appear to be a very attractive proposition from a socio-economic point of view. Except in the case of an unexpected change in the economic conditions we cannot count on any reversal in the tendency towards higher engine speeds (which increased by 25 percent per year on average over the period 1960 to 1970).

II$_{3.4}$. NOVEL ENGINES

A considerable reduction in noise levels can be expected in the case of the operation of vehicles driven by electric motors or by external combustion engines.

However, even with these vehicles it will be necessary to deal with noise coming from sources other than the driving unit (mechanisms, accessories, transmissions, wheel-road contact) in order to obtain significant reductions in the overall noise level.

II$_4$. INTAKE AND EXHAUST NOISE

The primary function of an exhaust system is to control the flow of gas coming from the engine so as to reduce the aerodynamic noise that would otherwise result in exhausting this high energy flow directly into the surrounding air. Thus a distinction can be made between the basic and residual aerodynamic noise at the output of the silencer and the noise emitted by the exhaust systems as a result of the vibration of the metal walls of that system, this vibration being a result of the coupling with the engine block and the excitation by the exhaust gas.

As regards the basic aerodynamic noise this can be reduced on increasing the volume of the silencer, by increasing the pressure loss or on using absorbent materials such as fibre glass. At the present time it is the first solution which has proved to be the most satisfactory. Thus we know how to design efficient silencers so far as the reduction of noise is concerned. This design can be based on established methods of calculation or on the use of electrical analogue systems the latter being employed to determine the best arrangement of the various pipes and gas decompression chambers fitted to the silencers.

The design problems here are those concerned with the size (larger systems are more effective) and the life of the exhaust system. In general exhaust systems are not sufficiently robust, have too short a life and are too readily affected by external weather and chemical conditions. These limitations contribute to the deficiencies of old motor vehicles with regard to the emission of noise. The use of steel having a longer life than that currently employed should result in the production of more robust silencers that will have a longer life but will presumably be more expensive such that a compromise between performance and overall cost will need to be made. (Research in France by Pechiney Cy.)

The exhaust systems of two-stroke engines (commonly fitted to two-wheel vehicles) are designed so that they can be dismantled for the removal of carbon and this feature can give rise to a degradation of the exhaust system due to the handling or to amateur repairs to the silencer chambers. Reductions in the oil content of fuel mixtures in the near future (currently recommended content: 4 percent; target content: 2 to 3 percent) should eliminate the production of carbon and two-stroke engines can then be equipped with permanently attached silencers. Meanwhile until this becomes possible manufacturers should consider the design of silencers that can be removed, but not dismantled, for the cleaning out of carbon.

As regards the noise radiated by the exhaust system this is limited at present on decoupling the system from the engine by means of flexible steel sleeves. This is an effective but not very robust arrangement since the sleeves are located in a high temperature region, more research is needed on this field.

In addition to the above considerations the development of anti-pollution devices, e.g., post combustion devices or catalysers, can in themselves give rise to new problems with regard to the exhaust system silencers. The development of such devices must on no account be carried out to the detriment of improvements made with regard to the effectiveness and life of silencers. Programs of work aimed at reducing noise and pollution respectively should proceed in parallel.

Intake noise can be reduced on making use of resonators or of tubes fitted with open cell material that absorbs the noise. The latter solution gives rise to reliability problems because of the degradation of the absorbent material with time. Both of these solutions are effective so far as the reduction of noise is concerned but there are problems because of their size.

II_5. ACTION CONCERNING FAN NOISE

The fan is a very significant source of noise on certain heavy vehicles. In addition to this it should be noted that the provision of hoods over the engines leads to the requirement for a greater cooling system capability and a consequent increase in fan noise if this possibility does not receive due attention.

Noise can be reduced on using high efficiency fans since these are generally quieter. Such fans usually have larger diameter blades and accordingly run at lower speeds.

The Bertin Cy in France studied the profile of the fan blades, the shape of the boss, the minimization of any play at the extremity of the fan blades and the position of the cooling system with respect to the engine with a view to increasing the aerodynamic efficiency so that it will be possible to run the fan at a lower speed. Fans that can be disengaged from the driving shaft are used if possible. Such attention can lead to the design of cooling systems that are consistent with enclosure of the engine, that are more efficient and that moreover meet the requirements to economize on the consumption of fuel.

II_6. ACTION ON THE TRANSMISSION

On some vehicles the transmission system connected to the engine generates an appreciable amount of noise. In these cases it is necessary to deal with the transmission in the same way as the engine or to enclose the system, for example, by means of a deck in the form of an extension of the screening plate beneath the engine. (ISVR, Metravib in Lyon.)

II_7. REDUCTION OF THE TOTAL VEHICLE NOISE

Providing all the more important sources of noise are dealt with it will be possible to achieve a significant reduction in the total noise emitted by motor vehicles such that the levels will be less than the maximum acceptable limits to be defined by the 1980 regulations. It will be easier to reduce the noise on certain vehicles than on others because of their smaller engines or the fact that more space is available. As a result of the investigations that have been made, particularly in France where manufacturers have been engaged in research with some financial support from the I.R.T., it is possible to predict orders of magnitude for the reduction in noise that could be achieved in practice in the future and of the costs of the recommended treatments.

It should be possible to achieve a reduction of 4 to 6 dBA, in terms of the ISO criteria, for private cars as a result of a partial or total enclosure of the engine, of attention to the cooling system and, in some cases, of modifications to the silencer.

A serious problem will arise in the case of small commercial vehicles (less than 3.5 tons) because of the lack of space for the installation of any enclosures and the provision of an adequate cooling system.

In general it is anticipated that the noise levels from medium weight and heavy goods vehicles could be reduced to:

- 86 dBA (ISO standard) as a result of major action on the accessories.
- Below 86 dBA as a result of partial or total enclosure of the engine and of modifications to the cooling system.

Some of the vehicles in this category will be more difficult to deal with than others particularly in the case of those fitted with small capacity, high speed engines.

Noise reducing treatment will be quite effective in the case of rear-engined buses since there is adequate space in this case for the enclosures and the provision of a larger capacity cooling system. Sound-proofed buses (80 dBA) have in fact already been produced.

Apart from the problem associated with the provision of more powerful cooling systems with larger radiators and fans all the proposed noise reducing treatments will involve the difficulty of finding suitable materials.

The limitations are not very significant so far as noise insulation is concerned (such as screens which rely on the mass of material involved) since any sufficiently dense material is suitable. However noise absorption which is an important function in the case of enclosures requires the use of materials that have suitable acoustic characteristics (efficient absorption over a wide range of frequencies) and that are also fire resistant, durable and compact. It is most important that investigations be made concerning the provision of suitable noise absorbing materials. The same remarks apply to the provision of damping materials (housing joints).

It should be noted that manufacturers have not so far had sufficient experience and are not yet able to take a sufficiently general view of the subject to be able to make an overall assessment concerning the effectiveness and in particular the reliability over a period of time of the recommended noise reducing treatments.

In particular there is not a proper understanding of the previously mentioned problems associated with enclosure of the engines. It is clear that these problems can only be resolved satisfactorily if they are taken into account at the preliminary design stage of a motor vehicle project.

There is also an inadequate appreciation of the effects of the noise reducing treatments on costs. It is difficult to estimate costs in the case of experimental vehicles and except for particular cases (sound-proofed buses) there is little information available at the moment on the direct costs of applying the proposed noise reducing treatments.

However, as a first approximation it is estimated that there will be a 1 percent increase in the cost of private cars for each 1 dBA reduction in noise level for the first few decibels of such a reduction and an increase of 20 to 35 kg in the vehicle weight for a reduction of 4 dBA in the noise level. In the case of medium weight lorries it should be possible to reduce the noise level to the 86 dBA target for a 3 to 4 percent increase in the cost of the vehicle (cabin plus chassis) and to 83 dBA for a 5 to 8 percent increase in this same cost.

The increases in vehicle costs will be somewhat less in the case of rear-engined buses: 3 to 4 percent for the target level of 84 dBA and 4 to 5 percent for a level of 80 dBA. The treatment here would involve an increase of about 50 kg in the weight of the vehicle and an increase in fuel consumption of about 1 litre/100 km.

There is a lack of data at the present time on the costs and weight increases in the case of the heavier lorries (maxi-codes) and of two-wheeled vehicles.

In addition to direct costs we need to allow for the effects on operating and maintenance costs. Certain treatments result in increases in the weight of the vehicle and the power of the cooling system and this leads to increased fuel consumption. In addition to this, badly designed noise reducing systems can impede access to the engine such that additional maintenance effort and hence expenditure is necessary.

It is also necessary to allow for the additional costs associated with the need to check the performance of sound proofing systems before leaving the factory and their subsequent maintenance during operation of the vehicle.

The cost of sound-proofing treatment depends very much on when it is applied. It costs more to apply such treatment to an existing vehicle which conforms to the present regulations but which was not originally designed to accommodate additional sound proofing equipment than it does when the same treatment is considered at the preliminary design stage of a projected vehicle when the sound proofing equipment can be integrated with other facilities. Satisfactory treatment to reduce noise cannot be based on makeshift or improvised solutions to the problems.

III. THE BRITISH VEHICLE PROGRAM

III_1. THE PROGRAM

The Quiet Heavy Vehicle (QHV) Project was initiated by TRRL in 1971. The QHV Project was aimed at demonstrating that practical heavy diesel-engined articulated vehicles could be produced with external noise levels which are some 10 dB(A) lower than the 1971 values (i.e., down to about 80 dB(A)) and secondly indicating the relationship between cost and noise level.

This class of vehicle was chosen as the first to be considered because it was thought to be the most difficult to quieten having the most powerful and noisiest engines.

The QHV Project has been coordinated by TRRL in cooperation with the other participating organizations and was divided into two main phases, (1) a research phase during which the various noise producing components of standard vehicles would be quietened by existing and new technology and (2) a development phase resulting in commercially viable vehicles for demonstration.

British manufacturers of commercial vehicles were approached and British Leyland, Fodens Ltd, and Rolls Royce Motors Ltd agreed to take part. The research on the basic noise producing components was entrusted to the Institute of Sound and Vibration Research (ISVR) at Southampton University, and the Motor Industry Research Association (MIRA) and lately the National Engineering Laboratory (NEL). TRRL undertook the work on tire-road surface noise.

Table 1 shows the allocation of work to the research organizations and table 2 the objectives.

TABLE 1. SOME EUROPEAN CENTERS WORKING IN THE FIELD OF VEHICLE NOISE

- INSTITUTE OF SOUND AND VIBRATION RESEARCH
  (PR PRIECE) - SOUTHAMPTON - U.K.
- INSTITUTE FOR INTERNAL COMBUSTION ENGINES
  (A.V.L.) - GRAZ - AUSTRIA
- INSTITUT FRANCAIS DU PETROLE
  (COMBUSTION NOISE) - PARIS - FRANCE
- OFFICE NATIONAL D'ETUDES AERONAUTIQUES
  PARIS - FRANCE
- TRANSPORT AND ROAD RESEARCH LABORATORY
  (MAINLY TIRE NOISE) - CROWTHORNE - U.K.
- METRAVIB
  ECULLY NEAR LYON - FRANCE - (ENGINE AND
  TRANSMISSION NOISE)

SOME EUROPEAN CENTERS WORKING IN THE FIELD OF HIGHWAY NOISE

- TRANSPORT AND ROAD RESEARCH LABORATORY
  CROWTHORNE - U.K.
- INSTITUT DE RECHERCHE DES TRANSPORT - CERN
  LYON-BRON - FRANCE
- INSTITUTE OF SOUND AND VIBRATION RESEARCH
  SOUTHAMPTON - U.K.
- BUILDING RESEARCH ESTABLISHMENT
  WATFORD - U.K.
- BUNDESANSTALT FUR STRASSENWESEN
  KOLN - GERMANY
- MULLER - BBM
  MUNCHEN - GERMANY
- TECHNISH PSYSISCHE DIENST TNO
  DELFT - NETHERLAND
- CENTRE SCIENTIFIQUE ET TECHNIQUE DU BATIMENT
  GRENOBLE - FRANCE

TABLE 2. NOISE OBJECTIVES FOR HEAVY TRUCKS

1 - At least 10 dB(A) less than initial levels
general target level down to 80 dB(A)

2 - 75 dB(A) inside the cab

3 - Compliance with all current and proposed vehicle construction and use regulations

4 - The exhaust noise target 69 dB(A) was extended to a low frequency noise maximum value of 90 dB(C).

OBJECTIVES FOR THE QUIET HEAVY TRUCK

Noise levels in dB(A) (ISO R362)	Engine and Transmission	Fan	Exhaust	Inlet	Total
Today's heavy truck	87.5-90	80-88	72-93	79.5	90
Target	74	74	74	74	80
Reduction	13.5-16	6-14	0-24	5.5	--

OBJECTIVES OF RENAULT VEHICULES INDUSTRIELS FOR HEAVY VEHICLE

III$_2$. THE RESULTS

As regards the components, the solutions which were eventually adopted:

- The engine - this is a Rolls Royce engine with 6 cylinders in line direct injection and water cooling, 13 litres cylinder volume, 320 Hp for 1950 r/mn (can reach 400 Hp). This engine has been altered in order to increase the rigidity of some of the elements (oil sump), to disconnect the radiating parts (with the help of specific materials and assembly devices), last to enclose some radiating surfaces with close screens fitted on parts that have low vibration levels. The result is simpler geometrical structure, slightly lighter than the former engine, offering the same performances though. Its acoustic power level has been considerably lowered (up to a 10 dB decrease).
- The gear box has been eventually enclosed; altering the structure of the box having proven inefficient.
- The transmission - no notable modification.
- The exhaust was altered through an increase of the silencer volume and an optimization, the disconnection of the exhaust tube is achieved through a flexible steel tube.
- The cooling was significantly altered, considering the engine was encapsulated. With the increased needs in the delivery and pressure of the cooling air it was necessary to use a mixed fan (axial, centrifuge) offering excelent aerodynamic and sound characteristics. Behind the quadrangular radiator several tubes were placed to ensure air circulation. The whole thing is rather bulky.
- Radial tires were chosen.

In the vehicle itself the main changes have arisen from all that room taken up by the cooling system. The bulk of its length lies behind the radiator, therefore the engine had to be that much displaced. It is encapsulated with a casing containing glasswool. The silencer is fixed transversally ahead of the for axle. It consists in two exhaust pipes in series with a total length of about 4 m by 28 m diameter.

Table 3 gives the results of the experiment. The 10 dB in the ISO norm is equally obtained for urban speeds. At high speed, the noise emitted by the tires become predominant and the dB cut is lesser.

TABLE 3. RESULTS

LENGTH	Tractor and maximum length trailer combination exceeds the permitted 15 m by 0.4 m (bulky fan)
WEIGHT	4 percent more equivalent to 0.8 percent of a fully laden tractor and trailer
COST	8-10 percent more than the standard vehicle
FUEL EFFICIENCY	Little different due to improvements in engine efficiency and lower cooling fan power consumption

Tire noise target is met at speed below 80 km/h
(75-77 dB(A) is exceeded 2-5 dB(A) at 100 km/h

Exhaust system noise	71 dB(A)	- 92 dB(C)
Engine	10 dB(A) less	

III$_3$. FOLLOWING PROGRAM

The program must end with a time of evaluation bearing on the vehicle performances in:

- acoustics (viability of the modifications)
- economics (effect on energy consumption)
- maintenance.

The results will put an end to the QHV program. It might be completed by a similar program on noise reduction concerning a light vehicle or a van.

III$_4$. CONCLUSION

The Quiet Heavy Vehicle program has been a success - what emerges is a practical vehicle compatible with the British regulations, thanks to industrial proceedings that assumed new technological solutions apparently trustful, (until the current works on the vehicle whole evaluation have been completed). Consequently the ISO 80 dB target is possible on a vehicle of that category belonging to the heaviest and most powerful which means the noisiest and most difficult to insulate.

Yet the solution raises some issues, for instance:

Is not the engine enclosure redundant with the insulation of the engine itself?

Is the low position of the silencer compatible with the normal use. It seems that the British legislation in this field is different form the French one?

Is the whole length of the vehicle acceptable?

IV. RAILWAY TRANSPORT

Some research and the use of efficient techniques have been developed for a number of years particularly about underground systems and trains, for we can remark that big European cities often resort to underground lines or modern tramways networks. In October '78, the second international workshop on railway noise was organized in Lyons by ISVR and IRT-CERN. Tires have been used in Paris and for the new systems in Lyons and Marseilles. This one avoids - in particular - the propagation of vibrations and low frequency radiations. Rolling noise is efficiently reduced by screens, in underground stations it is perfectly possible to use conventional absorbents. Studying the iron-against-iron rolling noise remains to be completed, there is no valuable result yet in Europe.

CONCLUSION

A great deal of rather conventional devices have been developed as a protection against railway and traffic noise. Research is wanted in the field of wheel and tire noise and weather-proof absorbents.

On the other hand what seems possible for the reduction of noise emitted by the vehicles is: minus 5 dB for cars, minus 10 dB for heavy trucks.

A development phase resulting in commercially viable vehicles is over as regards buses and well under way as regards trucks. Now we may have some concern with the low frequency noise emitted by the vehicle.

Getting higher noise reduction requires research on materials to be used in such milieu as the exhaust and around the engine. Technological development could also concentrate on the whole cooling system of thermic engines.

As for the main industrial tendencies today we believe the major steps taken now for example by electronics are not going to interfere favorably with our sound environment contrary to our air pollution. We might be more optimistic as regards the works on ceramics applied to thermal engines but Europe has not gone very far yet in this field.

APPENDIX A

ATTENDEES AT THE
U.S. ENVIRONMENTAL PROTECTION AGENCY
NOISE TECHNOLOGY RESEARCH SYMPOSIUM

SYMPOSIUM PARTICIPANTS

Moderator

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Office of Noise Abatement and Control

Opening Remarks

Ms. Adelene Harrison
Regional Administrator
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Keynote Speakers

Mr. Charles L. Elkins
Deputy Assistant Administrator for Noise Control Programs
U.S. Environmental Protection Agency

Mr. Carl Gerber
Executive Office of the President
Office of Science and Technology Policy

Dr. George Jacobson
U.S. Senate Staff
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Richard Edsell
U.S. Department of Labor

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*Session Leaders

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Joe Kolonko
Cincinnati Milacron

James Moreland
Westinghouse Electric Corporation

Everett Quade
Alcoa Technical Center

Samuel Sarkisian
Verson Allsteel Press Company

Harold Spuhler
National Science Foundation

Edwin Toothman
Representing Industrial Fasteners Institute, and American Iron and Steel Institute

Woodford Van Tifflin
General Motors Corporation

Istvan Ver
Bolt Beranek and Newman, Incorporated

Subgroup B
Lumber, Wood, Furniture, and Paper

*Edwin Bounous
Woodworking Machinery Manufacturers of America (Consultant)

*John Stewart
North Carolina State University

Donald Crawford
Weyerhaeuser Company

C. B. Dahl
Beloit Corporation

Robert Hershey
Science Management Corporation

Gary H. Koopmann
University of Houston

B. Andrew Kugler
Bolt Beranek and Newman, Incorporated

Kenneth Patrick
Western Wood Products Association

Howard Pelton
Pelton/Blum, Incorporated

Subgroup C
Chemical, Petroleum, and Electric Utility

*Terrence Dear
E.I. Du Pont de Nemours and Company

Stephen M. Blazek
Department of the Navy

*Allen Teplitzky
Consolidated Edison Company
of New York

Joseph Bhavsar
C.E. Lummus Company

Paul Kannapell
Monsanto Company

Vinay Nagpal
Control Components,
Incorporated

James Peat
Shell Oil Company

Richard Schoeller
David Taylor Naval Ship
Research and Development
Center

T. James DuBois
Southern California Edison

Charles Hickman
Southern Company Services,
Incorporated

James Seebold
Standard Oil of California

William Thornton
Gulf Research and Development

Michael Trykoski
Edison Electric Institute

Subgroup D
Food, Tobacco, and Glass

*R. A. Cassanova
Georgia Institute of
Technology

*Renny Norman
IIT Research Institute

Ray Gilbert
NASA

Lewis Goodfriend
Lewis S. Goodfriend &
Associates

Paul Jensen
Bolt Beranek and Newman,
Incorporated

James Maddrey
R. J. Reynolds Tobacco
Company

Richard Miller
Richard K. Miller & Associates,
Incorporated

N. Duke Perreira
University of Texas

Richard Robertson
Philip Morris, USA

David Ulrich
Corning Glass Works

Stanley Waggoner
University of California
at Davis

Subgroup E
Textile and Printing

*Paul Emerson
North Carolina State
University

*L. Phillips Thomas
Burlington Industries,
Incorporated

Douglas Anderson
Rockwell International

Lawrence Bain
Rockwell International

Donald Bastian
Harris Corporation

Melvin Jacob
U.S. Government Printing Office

John Kieronski
Whitten-Robert Machine Works

Donald Lyons
Clemson University

Ellis Pardue
Hanes Corporation

James Pullen
Celanese Fibers Company

Subgroup F
Underground Mining and Surface Processing Plants

*William Patterson
Gardner-Denver Company

*L. Alan Weakly
St. Joe Minerals Corporation

Erik Ahlberg
Atlas Copco (Sweden)

Edward Bailey
Joy Manufacturing Company

John Campbell
Peabody Coal Company

J. Harrison Daniel
Bureau of Mines

George Diehl
Ingersoll-Rand Company
(Consultant)

Edward Ellingson
Allis Chalmers

James Ferguson
Climax Molybdenum Company

Richard Holmquist
American Mining Congress

Richard Madden
Bolt Beranek and Newman,
Incorporated

John Seiler
Mine Safety and Health
Administration

William Shelton
Peabody Coal Company

Robert Slone
Wyle Laboratories

Subgroup G
Surface Mining and Construction

*John Damian
Ford Motor Company

*John McNally
Representing Construction Industry Manufacturers Association

Larry Bares
Peabody Coal Company

Robert Baron
Citizens for a Quieter City, Incorporated

Cliff Godsey
John Deere Dubuque Works

John Harris
JI Case

Lewis Held
Terex-Division of General Motors

Louis LeBlanc
Joy Manufacturing Company

A. Dennis Loken
Fiat-Allis Construction Machinery, Incorporated

Walter H. Page
International Harvester

Paul Schomer
U.S. Army Construction Engineering Research Laboratory

SURFACE TRANSPORTATION WORKSHOP
SUBGROUP ASSIGNMENTS

Edwin Ratering
General Motors Corporation
Chairman

Bernard Vierling
UMTA, Department of Transportation
Co-Chairman

Subgroup A
Exterior Sound Propagation in the Community and Vehicle Interior Noise

*Bernard Vierling
UMTA, Department of Transportation

*Ronald Wasko
Motor Vehicle Manufacturers Association

Timothy Barry
Federal Highway Administration

Richard Bauman
B. F. Goodrich

Claude Lamure
Institut de Recherche des Transports
(Bron, France)

Alvin Marshall
Ford Motor Company

Frank Matyja
General Tire and Rubber Company

D. H. Robbins
University of Michigan

Wesley Schwieder
Ford Motor Company

Edward Shalis
U.S. Army Tank and Automotive Command

S. Martin Taylor
McMasters University (Canada)

Donald Whitney
General Motors Corporation

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*Session Leaders

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Subgroup B
Engines and Propulsion Systems

*Robert Mason
U.S. Department of Transportation

*Rodger Ringham
International Harvester

H. A. Cook
Mack Truck Incorporated

Damon Gray
U.S. Environmental Protection Agency

William Hammer
General Motors Corporation

Robert Hellweg
State of Illinois Environmental Protection Agency

Dennis Kabele
John Deere Product Engineering Center

Detleff Karstens
Volkswagenwerk (Germany)

Richard Lyon
Massachusetts Institute of Technology

Daniel Maxfield
U.S. Department of Energy

Charles Moon
White Motor Corporation

Ben Sharp
Wyle Laboratories

Joseph Sullivan
Purdue University

James Valus
Electro Motor Division of General Motors

Subgroup C
Intake, Exhaust, Cooling, and Allied Engine Subsystems

*Erich Bender
Bolt Beranek and Newman, Incorporated

*Tony Embleton
National Research Council (Canada)

Peter Cheng
Stemco, Incorporated

Larry Eriksson
Nelson Industries

Robert Frantz
Chrysler Corporation

Raymond Gorman
Ryder Truck Rental

James Groening
H.L. Blachford,
Incorporated

Frederick Krey
GMC Truck and Coach

James Lewis
United Parcel Service

Nicholas Miller
International Harvester

Charles Preuss
Volkswagen of America,
Incorporated

Douglas Rowley
Donaldson Company, Incorporated

Max Rumbaugh
Wallace Murray Corporation

Larry Schaefer
American Motors Corporation

Subgroup D
Interaction of Tire/Roadway and Wheel/Rail

*Robert Hickling
General Motors Research
Laboratories

*Eugene Lehr
U.S. Department of
Transportation

Jozef DeEskinazi
Cooper Tire and Rubber
Company

Larry Dorsch
The Firestone Tire and
Rubber Company

John Eagleburger
The Goodyear Tire and
Rubber Company

Allen Eberhardt
North Carolina State
University

Conan Furber
Association of American
Railroads

William Gibson
American Trucking Association

John Koper
Federal Railroad Administration

Leonard Kurzweil
U.S. Department of
Transportation

James Lawther
Pennsylvania State University

William Leasure
National Highway Traffic
Safety Administration

Seymour Lippmann
Uniroyal Tire Company

Spencer Lucus
Dunlop Tire and Rubber
Company

Anthony Paolillo
New York City Transit
Authority

Jerry Reagan
Federal Highway Administration

AVIATION WORKSHOP
SUBGROUP ASSIGNMENTS

Jack Kerrebrock
Massachusetts Institute of Technology
Chairman

Harvey Hubbard
NASA
Co-Chairman

Subgroup A
Airframe

*Donald Lansing
NASA

*William Sperry
U.S. Environmental Protection Agency

Niels Andersen
Pan American World Airways, Incorporated

Warren Ahtye
NASA

Martin Fink
United Technologies Research Center

Jack Gibson
Lockheed-Georgia Company

C. G. Hodge
Boeing Commercial Airplane Company

Thomas Hodgson
North Carolina State University

K. Karamcheti
Stanford University

Robert Pendley
McDonnell Douglas Corporation

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*Session Leaders

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Subgroup B
Rotor and Propeller Noise

*Charles Cox
Bell Helicopter

*Frederick Metzger
Hamilton Standard

Donald Ahrens
Cessna Aircraft Company

Fereidoun Farassat
Joint Institute (George
Washington University/NASA)

Clyde Fitzgerald
Santa Monica Airport

George Greene
NASA

E. H. Hooper
Beech Aircraft Corporation

Harvey Hubbard
NASA

Frederick Schmitz
NASA

John Wesler
Federal Aviation Administration

Subgroup C
Propagation

*Aubert McPike
McDonnell Douglas Aircraft
Company

*Lou Sutherland
Wyle Research/Wyle Labs

Jeffrey Bowles
NASA

Clifford Bragdon
Georgia Institute of
Technology

Walter Collins
Los Angeles Department of
Airports

R. E. Coykendall
United Airlines

John Large
Southampton University
(England)

Richard Linn
American Airlines,
Incorporated

Michael Lorette
Boeing Commercial Airplane

S. Paul Pao
NASA

Walter Rockenstein
City of Minneapolis

Nathan Shapiro
Lockheed-California Company

Steve Starley
U.S. Environmental Protection Agency

Allen Stewart
U.S. Navy

Allan Zuckerwar
Old Dominion University

Subgroup D
Engine Noise

*Robert Lee
General Electric Company

*Homer Morgan
NASA

Gordon Banerian
NASA

Kenneth Bushell
Rolls Royce Limited

Charles Feiler
NASA

Derrick Higton
British Embassy

R. G. Hoch
S.N.E.C.M.A.
(France)

A.K.M.F. Hussain
University of Houston

Jack Kerrebrock
Massachusetts Institute of Technology

Lucio Maestrello
NASA

Ramani Mani
General Electric Company
(California Institute of Technology)

Paul Massier
Jet Propulsion Laboratory

Robert McGregor
Wright Patterson Air Force Base

A. A. Mikolajczak
Pratt & Whitney Aircraft

Richard Nagel
City of El Segundo

Robert Pendley
McDonnell Douglas Corporation

Mariano Perulli
Office National D'Etudes et de Recherches Aerospatiales
(France)

Richard Russell
Boeing Commercial Airplane Company

Edward Smith
General Electric Company

John Tyler
N.O.I.S.E.

Uwe von Glahn
NASA

Craig Wilson
AVCO Lycoming Division

APPENDIX C

PROGRAM AGENDAS FOR:

MACHINERY AND CONSTRUCTION EQUIPMENT WORKSHOP
SURFACE TRANSPORTATION WORKSHOP
AVIATION WORKSHOP

MACHINERY AND CONSTRUCTION EQUIPMENT PROGRAM

SUNDAY, JANUARY 28, 1979

7:00–9:30 pm	**MAIN REGISTRATION PERIOD**	Centre Complex Lobby
8:30–10:00 pm	Meeting of Project Advisory Committee (Workshop Chairmen and Co-Chairmen) and Advisory Panel Members	Montreal Room

MONDAY, JANUARY 29, 1979

7:45–8:30 am	**FINAL REGISTRATION**	Centre Complex Lobby

PLENARY SESSION
Keynote Speakers

8:30–8:40 am	Welcome by Adelene Harrison Regional Administrator, Region 6, U.S. EPA	New York City Room
8:40–8:50 am	Introduction by John C. Schettino Director, Technology and Federal Programs Division, U.S. EPA Office of Noise Abatement and Control (ONAC)	
8:50–9:15 am	Charles L. Elkins, Deputy Assistant Administrator for Noise Control Programs, U.S. EPA	
9:15–9:40 am	Carl Gerber, Executive Office of the President, Office of Science and Technology Policy (OSTP)	
9:40–10:05 am	George Jacobson, U.S. Senate Environment and Public Works Committee Staff	
10:05–10:30 am	Claude Lamure Institut de Recherche des Transports Bron, France	

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10:30–10:45 am	**BREAK** At conclusion of refreshment break participants divide into three separate and concurrently functioning workshops	Centre Complex Foyer
10:45–Noon	**WORKSHOP SESSIONS** Federal Agency representatives present noise technology research program updates. Questions and Comments	London Room
	Speakers:	
10:45–11:15 am	J. Harrison Daniel DOI/Bureau of Mines	
11:15–11:35 am	Questions and Answers	
11:35–11:50 am	Harold A. Spuhler National Science Foundation	
11:50–Noon	Questions and Answers	
Noon–1:30 pm	**LUNCH**	Open
1:30–1:45 pm	Stephen M. Blazek DOD/U.S. Navy	
1:45–2:00 pm	Questions and Answers	
2:00–2:15 pm	William N. McKinnery, Jr. DHEW/National Institute for Occupational Safety and Health	
2:15–2:30 pm	Questions and Answers	
2:30–3:00 pm	General discussion of the total Federal program	
3:00–3:15 pm	**BREAK**	Centre Complex Foyer
3:15–5:30 pm	**WORKSHOP SESSIONS** 15 minute review of issues to be addressed in workshop and sub-group sessions followed by questions and comments from participants	London Room

	Speakers:	
3:15–3:30 pm	**Issue #1** Robert D. Bruce Bolt, Beranek and Newman, Inc.	
3:30–3:40 pm	Questions and Answers	
3:40–3:55 pm	**Issue #2** Frank D. Hart N.C. State University	
3:55–4:05 pm	Questions and Answers	
4:05–4:20 pm	**Issue #3** Terrence A. Dear E.I. du Pont De Nemours and Company	
4:20–4:30 pm	Questions and Answers	
4:30–4:45 pm	**Issue #4** John J. McNally Catepillar, Tractor Company representing CIMA	
4:45–4:55 pm	Questions and Answers	
4:55–5:30 pm	**GENERAL DISCUSSION** Discussion of ground rules and method of operation for symposium	
6:30–7:30 pm	**SOCIAL HOUR** (Cash Bar)	International Ballroom
7:30–9:30 pm	**BANQUET DINNER**	International Ballroom

TUESDAY, JANUARY 30, 1979

8:00–5:30 pm	**SUB–GROUP SESSIONS** Workshop subdivides into sub-groups to address workshop issues	
	Machinery & Construction Equipment Sub–Groups	
	A – Metals/Fabrication	Hong Kong Room
	B – Wood/Paper	Mexico City Room

	C – Chemical/Petroleum/ Electric Utility	Copenhagen Room
	D – Food/Tobacco/Glass	Montreal Room
	E – Textile/Printing	Frankfurt Room
	F – Underground Mining/Surface Processing Plants	Brussels Room
	G – Construction/Surface Mining	Rome Room
8:00–10:00 am	**Issue #1**: What is the status of Noise Control Technology?	
10:00–10:15 am	**BREAK**	Centre Complex Foyer
10:15–12:10 pm	**Issue #2**: What role should the Federal Government play in developing Noise Control Technology?	
12:10–1:30 pm	**SYMPOSIUM GROUP LUNCHEON**	International Ballroom
1:30–3:20 pm	**Issue #3**: What role should the private sector play in developing Noise Control Technology?	
3:20–3:35 pm	**BREAK**	Centre Complex Foyer
3:35–5:30 pm	**Issue #4**: How and in which areas can government and industry work together on Noise RD&D programs?	
5:30–7:30 pm	**DINNER BREAK**	Open
7:30–10:30 pm	Project Advisory Committee Chairmen, Co–Chairmen, and Advisory Panel Members meet to develop summary outline	New York City Room
	Machinery & Construction Equipment Chairmen, Co–Chairmen and Advisory Panel members working group	London Room

WEDNESDAY, JANUARY 31, 1979

8:00–10:00 am	**WORKSHOP SESSION** Plenary review within Machinery & Construction Equipment Workshop of prior day's results. Presentation of findings, majority and minority opinions to Workshop before presentation to full Plenary Session	London Room
10:00–10:15 am	**BREAK**	Centre Complex Foyer
10:15–12:30 pm	**PLENARY SESSION** All participants assemble to review and discuss results of Workshop Activities	New York City Room
10:15–10:45 am	**AVIATION**	
10:45–11:15 am	**MACHINERY & CONSTRUCTION EQUIPMENT**	
11:15–11:45 am	**SURFACE TRANSPORTATION**	
11:45–12:30 pm	**GENERAL DISCUSSION AND DEVELOPMENT OF WORKSHOP CONCLUSIONS**	
12:30 pm	**ADJOURNMENT**	

SURFACE TRANSPORTATION PROGRAM

SUNDAY, JANUARY 28, 1979

7:00–9:30 pm	**MAIN REGISTRATION PERIOD**	Centre Complex Lobby
8:30–10:00 pm	Meeting of Project Advisory Committee (Workshop Chairmen and Co-Chairmen) and Advisory Panel Members	Montreal Room

MONDAY, JANUARY 29, 1979

7:45–8:30 am	**FINAL REGISTRATION**	Centre Complex Lobby

PLENARY SESSION

Keynote Speakers

8:30–8:40 am	Welcome by Adelene Harrison Regional Administrator, Region 6, U.S. EPA	New York City Room
8:40–8:50 am	Introduction by John C. Schettino Director, Technology and Federal Programs Division, U.S. EPA Office of Noise Abatement and Control (ONAC)	
8:50–9:15 am	Charles L. Elkins, Deputy Assistant Administrator for Noise Control Programs, U.S. EPA	
9:15–9:40 am	Carl Gerber, Executive Office of the President, Office of Science and Technology Policy (OSTP)	
9:40–10:05 am	George Jacobson, U.S. Senate Environment and Public Works Committee Staff	
10:05–10:30 am	Claude Lamure Institut de Recherche des Transports Bron, France	

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10:30–10:45 am	**BREAK** At conclusion of refreshment break participants divide into three separate and concurrently functioning workshops	Centre Complex Foyer
10:45–Noon	**WORKSHOP SESSIONS** Federal Agency representatives present noise technology research program updates. Questions and Comments	Sydney Room
	Speakers:	
10:45–10:55 am	Eugene Lehr DOT/Office of Environment and Safety	
10:55–11:10 am	Leonard G. Kurzweil DOT/Urban Mass Transportation Administration	
11:10–11:25 am	Timothy M. Barry DOT/Federal Highway Administration	
11:25–11:35	John Koper Robert L. Mason DOT/Federal Railroad Administration	
11:35–Noon	General discussion of the DOT program	
Noon–1:30 pm	**LUNCH**	Open
1:30–1:45 pm	Edward Shalis U.S. Army/Tank and Automotive Command	
1:45–2:00 pm	Questions and Answers	
2:00–2:15 pm	Damon Gray U.S. EPA, Office of Noise and Abatement and Control	
2:15–2:30 pm	Questions and Answers	
2:30–3:00 pm	General discussion of the total Federal program	

3:00–3:15 pm	**BREAK**	Centre Complex Foyer
3:15–5:30 pm	**WORKSHOP SESSIONS** 15 minute review of issues to be addressed in workshop and sub-group sessions followed by questions and comments from participants	Sydney Room
	Speakers:	
3:15–3:30 pm	**Issue #1** Erich K. Bender Bolt, Beranek and Newman, Inc.	
3:30–3:40 pm	Questions and Answers	
3:40–3:55 pm	**Issue #2** Bernard J. Vierling DOT/Urban Mass Transportation Administration	
3:55–4:05 pm	Questions and Answers	
4:05–4:20 pm	**Issue #3** Robert Hickling General Motors Research Labs	
4:20–4:30 pm	Questions and Answers	
4:30–4:45 pm	**Issue #4** Rodger Ringham International Harvester	
4:45–4:55 pm	Questions and Answers	
4:55–5:30 pm	**GENERAL DISCUSSION** Discussion of ground rules and method of operation for symposium	
6:30–7:30 pm	**SOCIAL HOUR** (Cash Bar)	International Ballroom
7:30–9:30 pm	**BANQUET DINNER**	International Ballroom

TUESDAY, JANUARY 30, 1979

8:00–5:30 pm	**SUB–GROUP SESSIONS** Workshop subdivides into sub-groups to address workshop issues	
	Surface Transportation Sub–Groups	
	A – Exterior Sound Propagation in the Community and Vehicle Interior Noise	Texican Room A
	B – Noise Control of Engines and Propulsion Systems	Texican Room B
	C – Noise Control of Intake, Exhaust, Cooling, and Allied Engine Subsystems	Bowie Room
	D – Noises from Interaction of Tire/Roadway and Wheel/Rail	Reagan Room
8:00–10:00 am	**Issue #1**: What is the status of Noise Control Technology?	
10:00–10:15 am	**BREAK**	Centre Complex Foyer
10:15–12:10 pm	**Issue #2**: What role should the Federal Government play in developing Noise Control Technology?	
12:10–1:30 pm	**SYMPOSIUM GROUP LUNCHEON**	International Ballroom
1:30–3:20 pm	**Issue #3**: What role should the private sector play in developing Noise Control Technology?	
3:20–3:35 pm	**BREAK**	Centre Complex Foyer
3:35–5:30 pm	**Issue #4**: How and in which areas can government and industry work together on Noise RD&D programs?	
5:30–7:30 pm	**DINNER BREAK**	Open
7:30–10:30 pm	Project Advisory Committee Chairmen, Co–Chairmen, and Advisory Panel Members meet to develop summary outline	New York City Room

	Surface Transportation Chairmen, Co-Chairmen and Advisory Panel members working group	Sydney Room

WEDNESDAY, JANUARY 31, 1979

8:00–10:00 am	**WORKSHOP SESSION** Plenary review within Surface Transportation Workshop of prior day's results. Presentation of findings, majority and minority opinions to Workshop before presentation to full Plenary Session	Sydney Room
10:00–10:15 am	**BREAK**	Centre Complex Foyer
10:15–12:30 pm	**PLENARY SESSION** All participants assemble to review and discuss results of Workshop Activities	New York City Room
10:15–10:45 am	**AVIATION**	
10:45–11:15 am	**MACHINERY & CONSTRUCTION EQUIPMENT**	
11:15–11:45 am	**SURFACE TRANSPORTATION**	
11:45–12:30 pm	**GENERAL DISCUSSION AND DEVELOPMENT OF WORKSHOP CONCLUSIONS**	
12:30 pm	**ADJOURNMENT**	

AVIATION PROGRAM

SUNDAY, JANUARY 28, 1979

7:00–9:30 pm	**MAIN REGISTRATION PERIOD**	Centre Complex Lobby
8:30–10:00 pm	Meeting of Project Advisory Committee (Workshop Chairmen and Co-Chairmen) and Advisory Panel Members	Montreal Room

MONDAY, JANUARY 29, 1979

7:45–8:30 am	**FINAL REGISTRATION**	Centre Complex Lobby

PLENARY SESSION

Keynote Speakers

8:30–8:40 am	Welcome by Adelene Harrison Regional Administrator, Region 6, U.S. EPA	New York City Room
8:40–8:50 am	Introduction by John C. Schettino Director, Technology and Federal Programs Division, U.S. EPA Office of Noise Abatement and Control (ONAC)	
8:50–9:15 am	Charles L. Elkins, Deputy Assistant Administrator for Noise Control Programs, U.S. EPA	
9:15–9:40 am	Carl Gerber, Executive Office of the President, Office of Science and Technology Policy (OSTP)	
9:40–10:05 am	George Jacobson, U.S. Senate Environment and Public Works Committee Staff	
10:05–10:30 am	Claude Lamure Institut de Recherche des Transports Bron, France	

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10:30–10:45 am	**BREAK** At conclusion of refreshment break participants divide into three separate and concurrently functioning workshops	Centre Complex Foyer
10:45–Noon	**WORKSHOP SESSIONS** Federal Agency representatives present noise technology research program updates. Questions and Comments	Mexico City Room
	Speakers:	
10:45–11:00 am	Robert McGregor DOD/U.S. Air Force	
11:00–11:15 am	Questions and Answers	
11:15–11:30 am	Gordon Banerian NASA, Headquarters	
11:30–12:10 pm	Charles E. Feiler Uwe H. von Glahn NASA, Lewis Research Center	
12:10–1:30 pm	**LUNCH**	Open
1:30–2:15 pm	Homer G. Morgan NASA, Langley Research Center	
2:15–2:45 pm	General discussion of the NASA program	
2:45–3:15 pm	General discussion of the total Federal program	
3:15–3:30 pm	**BREAK**	Centre Complex Foyer
3:30–6:00 pm	**WORKSHOP SESSIONS** Presentation of papers on status of Aviation noise control technology	Mexico City Room
	Speakers:	
3:30–3:55 pm	**CTOL** Richard E. Russell Boeing Company of America (Questions and Answers)	

3:55–4:20 pm	**CTOL** Robert E. Pendley McDonnell Douglas Corporation (Questions and Answers)	
4:20–4:45 pm	**STOL** Jeffrey Bowles Michael Shovlin NASA, Ames Research Center (Questions and Answers)	
4:45–5:10 pm	**ROTARY WING** Charles R. Cox Bell Helicopter (Questions and Answers)	
5:10–5:35 pm	**SST** Gordon Banerian NASA Headquarters (Questions and Answers)	
5:35–6:00 pm	**GENERAL DISCUSSION** Discussion of ground rules and method of operation for symposium	
6:30–7:30 pm	**SOCIAL HOUR** (Cash Bar)	International Ballroom
7:30–9:30 pm	**BANQUET DINNER**	International Ballroom

TUESDAY, JANUARY 30, 1979

8:00–5:30 pm	**SUB–GROUP SESSIONS** Workshop subdivides into sub-groups to address workshop issues	
	Aviation Sub–Groups	
	A – Airframe Noise	Amsterdam Room
	B – Rotor & Propeller Noise	Sydney Room
	C – Propagation	London Room
	D – Engine Noise	Paris Room
8:00–9:30 am	**Issue #1**: What is the status of Noise Control Technology?	
9:30–10:00	**Issue #2**: What role should the Federal Government play in developing Noise Control Technology?	

10:00–10:15 am	**BREAK**	Centre Complex Foyer
10:15–11:15 am	**Issue #2** Discussion Continues (Questions and Answers)	
11:15–Noon	**Issue #3**: What general and specific areas require Federal research support? What programs in progress require further emphasis?	
Noon–1:30 pm	**SYMPOSIUM GROUP LUNCHEON**	International Ballroom
1:30–2:15 pm	**Issue #3** Discussion Continues (Questions and Answers)	
2:15–3:15 pm	**Issue #4**: What role should the private sector play in developing noise control technology?	
3:15–3:30 pm	**BREAK**	Centre Complex Foyer
3:30–4:00	**Issue #4** Discussion Continues (Questions and Answers)	
4:00–5:30 pm	**Issue #5**: Are there demonstration programs needed to stimulate the adoption of advanced noise technology? (Questions and Answers)	
5:30–7:30 pm	**DINNER BREAK**	Open
7:30–10:30 pm	Project Advisory Committee Chairmen, Co-Chairmen, and Advisory Panel Members meet to develop summary outline	New York City Room
	Aviation Chairmen, Co-Chairmen, and Advisory Panel members working group	Mexico City Room

WEDNESDAY, JANUARY 31, 1979

8:00–10:00 am	**WORKSHOP SESSION** Plenary review within Aviation Workshop of prior day's results. Presentation of findings, majority and minority opinions to Workshop before presentation to full Plenary Session	Mexico City Room
10:00–10:15 am	**BREAK**	Centre Complex Foyer
10:15–12:30 pm	**PLENARY SESSION** All participants assemble to review and discuss results of Workshop Activities	New York City Room
10:15–10:45 am	**AVIATION**	
10:45–11:15 am	**MACHINERY & CONSTRUCTION EQUIPMENT**	
11:15–11:45 am	**SURFACE TRANSPORTATION**	
11:45–12:30 pm	**GENERAL DISCUSSION AND DEVELOPMENT OF WORKSHOP CONCLUSIONS**	
12:30 pm	**ADJOURNMENT**	

APPENDIX D

ISSUES FOR:

MACHINERY AND CONSTRUCTION EQUIPMENT WORKSHOP
SURFACE TRANSPORTATION WORKSHOP
AVIATION WORKSHOP

MACHINERY AND CONSTRUCTION EQUIPMENT WORKSHOP ISSUES

1. What is the status of Noise Control Technology?
    a. What major noise related research programs does industry (corporations and trade associations) have underway (Federal have already been identified)?
    b. What are the principal approaches available to reduce equipment and process noise?
    c. What are some of the major types of equipment and processes for which noise control methods are unavailable?
    d. Has there been noise abatement technology transference from one product/process to another?
    e. What research should be done?
2. What role should the Federal government play in developing Noise Control Technology?
    a. What factors should influence Federal involvement in noise research?
    b. For what products, processes, and industries should the Federal government be undertaking noise research?
    c. What other areas of noise generation should receive Federal research support?
    d. What future technology developments will influence noise control and/or research?
    e. What balance should be given to support for demonstration programs and research to develop new technology?

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3. What role should the private sector play in developing Noise Control Technology?

   a. Can industry solve the noise problems without input and assistance of the Federal government?

   b. What are the incentives for noise control RD&D by equipment manufacturers and users?

   c. In what specific areas should noise control research be done by private industry?

   d. What are the constraints that inhibit development of noise control technology by industry?

   e. Waht role should educational institutions play in RD&D for the industrial, and machinery and construction equipment areas?

4. How and in which areas can government and industry work together on Noise RD&D programs?

   a. What method/procedures can be utilized to disseminate and implement the results of successful RD&D programs?

   b. What are the principal factors that need to be shown in demonstration programs to encourage adoption by industry?

   c. What forum or mechanism can be used effectively to provide for an exchange between government and industry concerning noise research needs and accomplishments?

SURFACE TRANSPORTATION WORKSHOP ISSUES

1. What is the status of Noise Control Technology?
    a. What are some of the major types of equipment for which noise control methods are unavailable?
    b. What are the principal approaches available to reduce equipment noise?
    c. What noise related research programs do industry (corporations and trade associations) have underway?
    d. Has there been noise abatement technology transference from one product/process to another?
2. What role should the Federal government play in developing Noise Control Technology?
    a. What factors should influence Federal involvement in noise research?
    b. For what products, and industries should the Federal government be undertaking noise research?
    c. What other areas of noise generation should receive Federal research support?
    d. What future technology development will influence noise control and/or research?
    e. What are the principal factors that need to be shown in demonstration programs to encourage adoption by industry?

3. What role should the private sector play in developing Noise Control Technology?

   a. Can industry solve the noise problems without input and assistance of the Federal government?

   b. What are the incentives for noise control RD&D by equipment manufacturers and users?

   c. In what specific areas should noise control research be done by private industry?

   d. What are the constraints that inhibit development of noise control technology by industry?

   e. What role should educational institutions play in solving noise problems?

4. How and in which areas can government and industry work together on Noise RD&D programs?

   a. What method/procedures can be utilized to disseminate and implement the results of successful RD&D programs?

   b. What specific noise control demonstration programs would aid equipment manufacturers and users to introduce noise control measures?

   c. What forum or mechanism can be used effectively to provide for an exchange between government and industry concerning noise research needs and accomplishments?

AVIATION WORKSHOP ISSUES

Five main issues:

1. What is the status of Noise Control Technology?

    a. CTOL (Carrier, general aviation/business jets)
    b. STOL
    c. Rotory Wing
    d. SST

2. What role should the Federal government play in developing Noise Control Technology?

3. What general and specific areas require Federal research support? What programs in progress require further emphasis?

    a. Engine noise
        (1) Jet
        (2) Turbomachinery
        (3) Core noise
        (4) Treatment
    b. Airframe
    c. Propellers and rotors
    d. Propagation

4. What role should the private sector play in developing noise control technology?

5. Are there demonstration programs needed to stimulate the adoption of advanced noise technology?

    a. Engine noise
        (1) Jet
        (2) Turbomachinery
        (3) Absorptive treatment
    b. Airframe
    c. Propellors and rotors
    d. Propagation

Ten "sub-issues" to support the course of the discussion on the five main issues and provide some specific informational needs:

a. How adequate is the national R&T program to establish fundamental understanding of the phenomena controlling noise production?

b. How adequate is the present capability for predicting the noise characteristics of a new design?

c. What elements are lacking in the national R&T program to establish adequacy in the above two senses?

d. What elements of the present Federal noise research program should be contracted or eliminated in favor of others of greater importance?

e. Are there demonstration programs needed to stimulate the adoption of advanced noise control technology?

f. Is the Federal program properly balanced between activities in: basic research, applied research. demonstration, and development?

g. Does the congressional mandate for Federal noise control research which results mainly from public pressure, provide a sound basis for the program, or should industry attempt to motivate the program?

h. What is the purpose of the Federal noise research program (e.g. establish a basis for regulation, etc.)?

i. Should there be a larger scale Federal program with longer term commitments?

j. Can and should the private sector be induced to put risk capital into noise research? How?

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